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AMERICAN INSTITUTE

OF

ELECTRICAL ENGINEERS.

SPECIAL MEETING, FEBRUARY 12TH, 1889.

SUBJECT:

A New System of Multiplex Telegraphy.

BY LIEUT. F. JARVIS PATTEN.

Lightning Arresters and the Photographic Study of Self-Induction.

NOTES BY JO. STANFORD BROWN AND CHAS. T. CHILD.

Reply to the Notes of Messrs. Brown and Child.

COMMUNICATED BY E. G. ACHESON.

NEW YORK CITY:
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AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

VOL. VI. New York, April, 1889. No. 4.

The thirty-second meeting of the Institute was held on Feb. 12, 1889, at the College of the City of New York. The meeting was called to order at 8.30 P. M. by the Secretary, who said:

"The subject first to be brought before you this evening is a paper by Lieut. F. Jarvis Patten, U. S. A., on "A New System of Multiplex Telegraphy." That will be followed by some notes on Mr. Acheson's paper, read January 8th, which will be presented by Mr. Jo. Stanford Brown, member of the Institute, and Mr. Chas. T. Child. These gentlemen have made some experiments, and prepared a brief paper based upon the same, giving reference to experiments which have been made in the past. These notes were prepared at the suggestion of Mr. Martin and myself, as the character of the paper was such that it could not be properly discussed at the last meeting. It will be necessary for you to appoint a chairman to serve for the evening."

On motion of Mr. Crocker, Mr. C. O. Mailloux was voted to the chair.

THE CHAIRMAN: I do not think it is necessary for me to make a set speech to introduce to you our friend and fellow member, Lieutenant Patten. He is a man who is already very well known to the Institute by the active interest he has taken in some discussions we have had at previous meetings, and he is also very well known from several inventions which have brought him prominently into notice. The system, which he brings before you this evening, is one which I am sure will be of great interest. The subject of synchronism in telegraphy is one which has attracted attention almost from the very first discovery of the telegraph, and you will find that as early as in the "forties," some patents were taken out for methods of attaining synchronism in telegraphy. Our

American electrician, Prof. Moses G. Farmer, I believe, was one who made himself distinguished in that field, as he has in a great many others in which he has been the pioneer, and in which he has been so unfortunate as to be ahead of his time. The subject was possibly brought up too early to receive that consideration which would enable results to be obtained that would be practical. It was necessary, perhaps, that the world should advance, that new principles should be elaborated and that new discoveries of laws, etc., should be made known before we could arrive at a practical application of the methods by which synchronism could be effected in telegraphy. I think the time has now arrived for such applications, and the fact that several methods of synchronism have already been brought forward shows that the matter is forced on our consideration, and that we have a right to expect the success of such methods. You will find that the method presented to you this evening is one which is in every respect worthy of the science.

Lieut. Patten then read the following paper.

A NEW SYSTEM OF MULTIPLEX TELEGRAPHY.

BY LIEUT. F. JARVIS PATTEN.

The paper this evening has a single object, its purpose being to describe the salient features of a system of multiplex transmission by telegraph, and as the system is still in the experimental stage, I shall have more to say concerning devices thus far used wherein practical results have come near to the indications of theory, than as to the actual possibilities of the system in use. The general subject is so familiar to all present that a review of the different methods of multiplex transmission is scarcely necessary. Suffice it to say that the system under consideration falls under the general class of synchronous multiplex telegraphs which depend for their operation upon the absolute or approximately uniform rate of movement of similar apparatus placed at the different stations of a line.

In the interest of those present who may not be familiar with the fundamental principle underlying all systems of multiplex transmission, I will give a brief description, which will be understood by reference to Fig. 9. A line wire is shown connecting two distant points, at each end of which is placed a machine which carries a revolving brush or trailer, which is caused by some form of mechanism to sweep over a circular table of contacts; this is subdivided as shown, into a convenient number of segments insulated from each other. Each of these segments is connected to a branch circuit, which includes all the necessary instruments for a single operator sending or receiving. If we consider the trailer motionless and resting on, say, the segment No. 10, then the two operators at the end of the line would each evidently find the main line connected to his sending and receiving apparatus for the time being, and if the trailer remained in the position shown they could hold uninterrupted communication with each other. If, now, the trailers were moved to the segments No. 15, in each distributor, then operators No. 15 at each

end would have the line. It will now be understood that if by any means the trailers could be revolved uniformly around the circle, the line would be given in turn to any number of operators connected, in the manner described, to the main line.

Early attempts at multiplex transmission did not go further than this. The line was given slowly first to one and then to another operator, the time that each in turn could hold communication being indicated by a common metronome. Later attempts went farther than this, the idea being to make the trailers revolve at a high rate of speed, moving, in fact, so fast that each pair of operators in turn is connected to the line so fast that he is practically unaware that the line has ever been taken from his circuit.

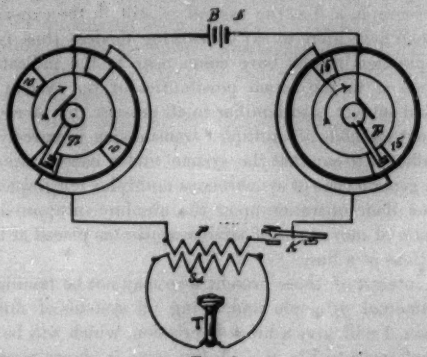

FIG. 9.

It is easy to see that this would not require a very high rate of speed. If it be assumed that the operator can make the shortest signal with his key in one-fifth of a second, it only becomes necessary to move the trailers at a speed of more than five revolutions in a second, when it would evidently be impossible for any of the operators to close a key without having the line during this interval connected to his branch circuit. In order that the signal sent by any operator shall reach the corresponding operator at the other end of the line, it becomes necessary, of course, that the trailer at the two stations should be on the same identical segments at the same instant of time. The solution of this problem will then consist in causing the trailers, however far apart, to move with absolute uniformity and precision. If this can be

done at a sufficiently high rate of speed, then a single wire may be given in rapid succession to a number of operators at each end, and all can simultaneously communicate over the single wire without interruption from, or interference with each other.

Such a system has for its object the utilization of all the currents which in a given unit of time can be distinctly transmitted over a single wire. If it is assumed that in average Morse transmission five pulsations of current or makes and breaks of the circuit occur in every second, then if n represent the number of separate currents that can be made to succeed each other during this interval of time $\frac{n}{5}$ will represent theoretically the number of receivers or operators that can work the same wire at the same time.

Any system based upon the foregoing theoretical consideration, which consists practically in giving the line for a brief interval of time to a number of operators in rapid succession, rests fundamentally upon the fact that the identical revolutions in the same period of time of certain parts of the apparatus at different stations can be maintained continuously; in other words, a perfect synchronizing device of some sort must be the fundamental starting point without which any such system will remain what a noted English scientist has aptly described as a "mere figment of the intellect."

In the literature of the telegraph, already large, synchronizing devices are common, and in the books their operativeness is generally taken for granted. All such devices, with a single exception that occurs to me, are founded upon the isochronous motion of some mechanism which, under the operation of natural forces, has a fixed rate of movement, and preserves this motion unvaried so long as these forces are acting freely. The pendulum and the tuning fork perform their oscillations of great or small amplitude in the same period of time; their rate of movement is, therefore, described as being *isochronous*. Two such exactly similar devices while in motion, therefore, should be in *synchronism* with each other; but all these devices once set in motion immediately tend to a state of rest, and it becomes necessary to apply constantly some extraneous force to keep them in continued operation; they must continually receive an intermittent impulse to prevent them from coming to a state of rest. The natural rate of movement of the apparatus, which is alone the result of the

uninterrupted action of the forces in the system, is thus made subject to a slight but constant disturbing effort.

In view of these considerations, which have been expressed in the most general terms, it has been my endeavor to perfect a synchronizing device that should be independent of the uniform rate of motion of any part, the general statement of the problem being to devise apparatus which shall move in unison with each other at a variable instead of a constant rate of speed. Recent electrical inventions point clearly to an ultimate solution of this problem, if it has not already been achieved. A pertinent illustration of this fact is found in the common speaking telephone,

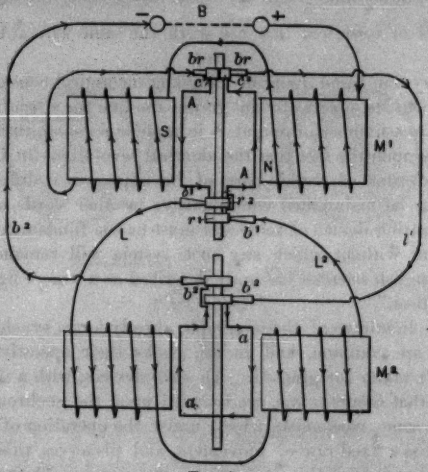

FIG. 1.

so common that variable synchronism is already in daily use among those who regard matters electrical as full of mystery. In this apparatus the diaphragm of the receiving instrument moves in perfect synchronism with that of the transmitter, and it seems by no means an exaggerated comparison to regard the receiver as an alternating current motor moving in perfect unison with the changes of potential in the generator and the line circuit. My experiments in this field were first directed to the application of this peculiar relation of the alternating current generator and motor to a synchronizing device, only to reach the conclusion,

however, that it could not be made operative on a circuit of any considerable length.

Further experiments led to a simpler solution of the problem involving few uncertain elements.

I had constructed two ordinary direct current motors of the simplest form, an ordinary two pole field and single coil armature conveniently arranged for use as either direct or alternating current machines. The armature circuits were connected at one end to an ordinary two-part commutator and at the other to two insulated ring contacts. They are shown by a simple diagram in Fig. 1, where both are connected in a single circuit. The armature of the machine M¹ was normally open at the ring contacts, and could be closed either by connecting the ring or through an external circuit. Such a circuit was made to include the field coils of the machine M², and the armature of this machine was connected in the direct current circuit from the poles of the battery. Thus connected, the two machines moved as one; the machine M² following all the fluctuations of speed in the machine M¹, as if their armatures were carried by the same spindle, the speed being varied between wide limits. To convert this mechanism into a synchronizing device in such a way that the machines could be placed at a great distance from each other was another step. As there was evidently an alternating current in the external loop connected to the armature of the first machine, the reversals of current in this circuit must correspond in time to the half revolutions of the armature of this machine, and an ordinary polarized relay connected in the loop would vibrate in unison with the half revolutions of the armature in the machine M¹. The second machine could therefore be made operative at a distance by simply connecting another relay in an independent line circuit and causing the latter to reverse the current in the second machine. This arrangement, which constitutes the fundamental synchronizing device, is shown in Fig. 2. Here the first machine placed at station X has a polarized relay connected in the external armature circuit, and the relay vibrates in response to the reversals of current in the armature of this machine, which correspond accurately to the half revolution of the machine at X. A line circuit extends from the fixed point of the relay vibrator to the distant station Z, where it includes the coils of another relay and returns to the middle point of the line battery L B at X, the opposite poles of which are connected to the contact stop

of the relay at this station. From these connections it results that any relays in the line circuit will be actuated by reversed currents in unison with the half revolutions of the machine at x. At any distant station, as the one shown at z, another machine has its field coils connected as follows: One terminal to the fixed point of the relay and the other to the middle point of a local battery, the opposite poles of which are connected to the contact stops of this relay, the armature of this machine being connected through ring contacts and brushes to an independent source of direct current. Connected in this manner, the two machines still move in perfect unison, even at variable speeds, though separated from each other by any line resistance through which a

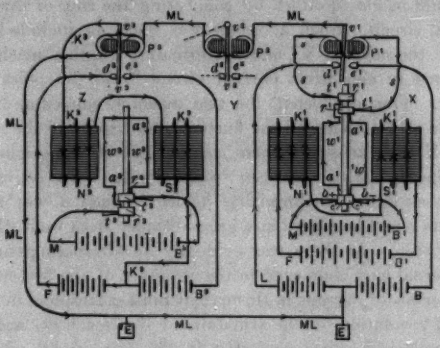

Fig. 2.

polarized relay can be made to act. With a single coil armature the driven machine is at times quite erratic, as it can evidently move in either direction, and I have seen such machines reverse instantly at a speed of several hundred revolutions a minute, and go apparently as fast in the opposite direction, and this even when provided with a flywheel of moderate weight.

This difficulty may be overcome in a variety of ways; an effective one is shown in Fig. 3, which represents a form now given to the armature of the driven machine. It has two coils in series connection, but wound with their poles at right angles to each other. This armature, being placed in a single field, I had supposed would move at only half of the speed of the first machine; but, on the contrary, the synchronism was perfect, the motion was

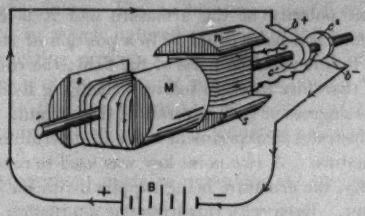

Fig. 3.

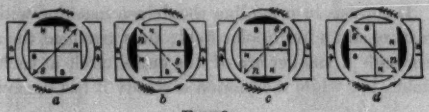

Fig. 3A.

continuous in direction and it has never been known to reverse. The analysis of its action is shown in Fig. 3A, where the armature is represented in the four successive quadrants of a single revolution, the black and the white pole pieces representing the ends of the two coils in their different positions. The dotted lines indicate the position of a pair of resultant poles which must lie diagonally between the actual poles; this diagonal line represents

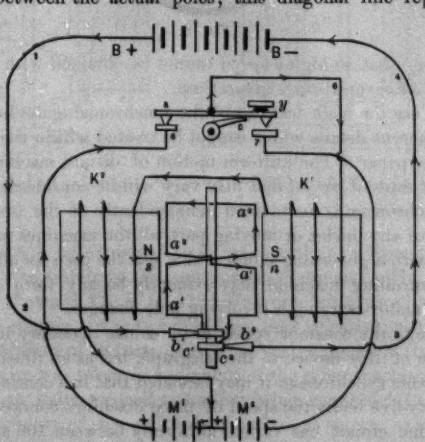

Fig. 3B.

the resultant polarity of the armature and it is evident that neither of its actual poles could be in a position of stable equilibrium while in line with the poles of the field; the resultant armature pole is therefore made to follow a changing field that moves through 180 degrees at each reversal of the current.

Fig. 3B illustrates an experiment made in determining a suitable form of armature. A two point key was used to reverse the field intermittently, the armature being supplied with an independent direct current. Even with this irregular alternation of the current the motion was still continuous. Another method of preserving absolutely steady synchronism is shown in the sketch Fig. 8. It consists in providing the driven machine with a single coil armature and a multipolar field; thus arranged the armature passes through a smaller arc of the entire circle at each reversal of the field; but while the motion is steady it has the evident dis-

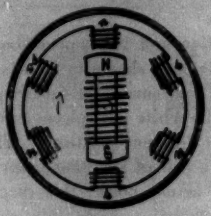

FIG. 8.

advantage that so high a speed cannot be obtained with the same number of reversals in a given time.

Such are the main features of the synchronizing device. There are numerous details which cannot be treated within the limits of a single paper. The uniform motion of distant machines is secured at rates of speed that may vary within considerable limits and synchronism is maintained independently of the isochronous motion of any device or moving part, all the machines moving in unison with a governing motor which sets the pace for all the rest. The controlling machine may evidently be any form of direct current motor carrying a revolving pole changer.

A practically constant speed is of course necessary in any application of this device to the telegraph, but as an illustration of the variable synchronism it may be stated that in a continuous run of twenty-five hours the speed of three machines connected by a single line circuit has varied uniformly between 100 and 1,000

revolutions per minute. Fig. 4 illustrates a modification of the original system in which induced currents of high E. M. F. are used as synchronizing currents. The armature loop of the governing machine is connected to the primary of an induction coil, the secondary to the line circuit at distant stations, and the impulses are reconverted and caused to actuate a polarized relay as before.

A simple experiment made to determine the accuracy of the

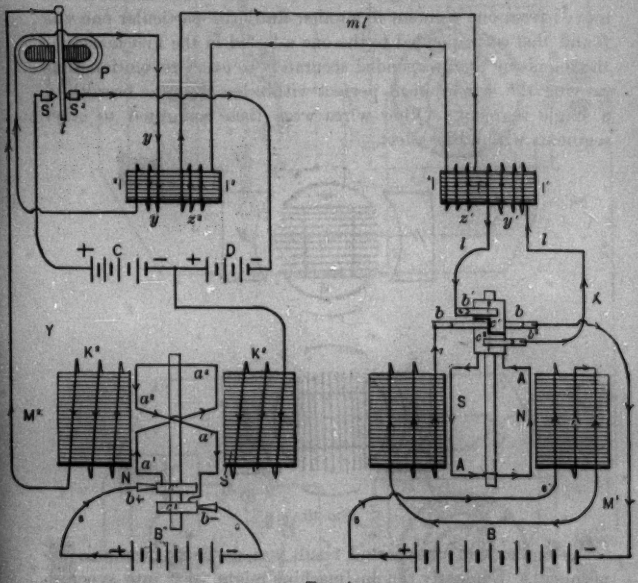

FIG. 4.

synchronism will be explained, as it led directly to a separate application of the system to the transmission of signals. The connections are shown in Fig. 9. (p. 112.) From the battery B a line extends to the spindle of the two machines, each provided with segmental distributors of 48 parts. From one such segment in the one machine a wire was taken to a segment of the other machine, the primary of an induction coil and a key being connected in this line, the secondary of the coil was connected, as shown, to an or-

dinary telephone receiver. If the machines were moving in unison, the circuit of the primary would be completed whenever the revolving trailers were simultaneously upon the connected segments in the two machines, and the key was closed. If either trailer were slightly in advance of, or behind the other there could be no primary circuit formed on closing the key, no induced current, and no sound in the telephone. The machines were driven at variable speeds, and the wire at one machine was moved from one segment to another until the particular one was found that corresponded to the one selected in the first machine; the telephone then responded accurately to every revolution, thus proving the synchronism perfect within less than the breadth of a single segment. Other wires were then connected to other segments with a like effect.

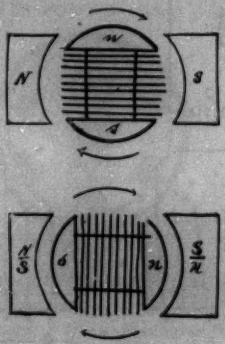

FIG 10.

A singular and unexpected result was deduced from this experiment. Evidently the one machine might start into synchronism at any point of the circumference, the trailers making any angle with each other, as the one shown in the diagram; a revolving switch had been provided which was so arranged that by turning it, a wire could be moved from one segment to another and so adjust the circuits independently of the relative positions of the trailers. The machines were repeatedly stopped and started again, but came again into synchronism always at the same point, the wires never requiring any adjustment, establishing clearly the singular fact that the driven machine always went into synchronism at the same point and could, therefore, be made to start in

at any point of the distributor by a proper adjustment of the trailer on the spindle. The reason for this may be found by considering the relation of the forces as expressed in the diagram

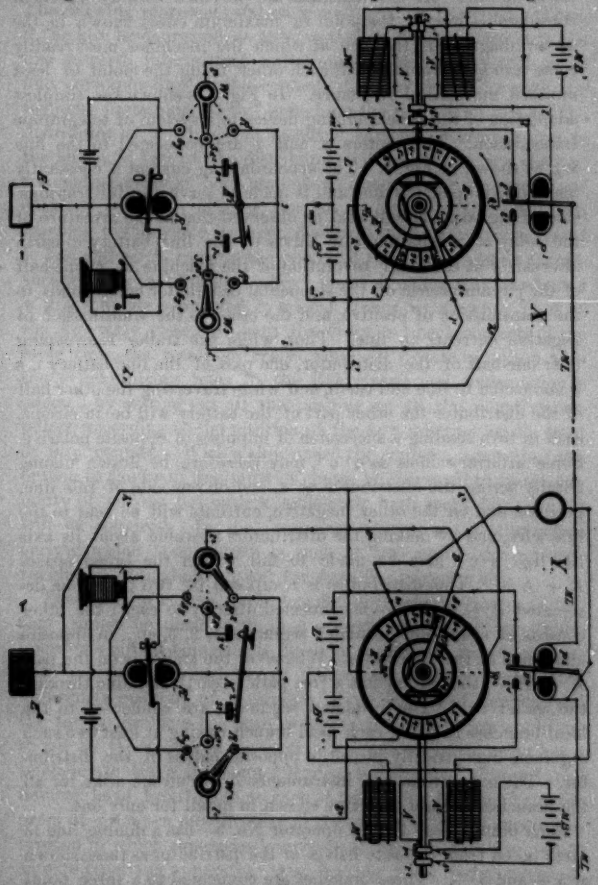

FIG. 5.

Fig. 10. Here the same machine is shown with the armature in two positions differing by 90 degrees, the first being a position of

maximum effort, while the second is a minimum as the field poles are changing to the opposite designation indicated by the lower letters. As the machines are provided with fly wheels of considerable weight, the point of maximum effort shown in the upper diagram is the one at which the machines most readily come into synchronism with each other, being the point of least opposed mechanical resistance. In Fig. 5 is shown the simplest adaptation of the synchronizing device to a system of telegraphic transmission. The motors X and Y are connected to the line M L, as shown in Fig. 2. The synchronizing current is constantly maintained upon the line and is made to serve also for transmission of signals. It will also be observed that as the armature of the relay at X puts opposite halves of the line battery to earth alternately at each half revolution of the machine at X, one-half of the circumference of the segmental distributor corresponds to the transmission of positive, and the other to the transmission of negative currents to line. Thus, while the trailer is sweeping over one-half of the distributor, one part of the line battery L B is connected to line and earth, and while traversing the other half of the distributor the other part of the battery will be in circuit, each in turn sending a succession of impulses of opposite polarity. Some arbitrary lines as $Q^1 U^1$, may therefore be drawn diametrically across the distributor at X, and on one side of this line, positive, and on the other, negative, currents will be sent to the line wire, and by making the distributors movable about its axis the line $Q^1 U^1$ may be made to fall within the broad spaces $E+ E-$. The distributor is composed of two parts, one designated $E+$, and $E-$ is connected directly to each; the other consists of a series of insulated segments 1, 2, 3, etc., in opposite quadrants of the distributor. Whenever the trailer is on the part $E+$, $E-$, the battery has a free path to earth and line through the trailer TR^1. The insulated segments are connected to the local branches in pairs, each local branch having at least two such segments diametrically placed in opposite halves of the distributor. The connections and instruments in circuit are alike for all the branches and are therefore shown in detail for only one.

Each branch—say that of operator No. 5—has a double line to earth taken from opposite halves of the distributor as those shown at 5 + and 5 —. These branches are connected to a three point switch w^1 and w^2, which may be turned to R^1 and R^2 for receiving, or to s^1 and s^2 for sending, thus throwing the key in

circuit, or sy^1 and sy^2 for synchronizing, thus leaving the sending and receiving apparatus out of circuit. An ordinary reversing key is used, the relay circuit being connected to its middle point. The drawing represents station X sending and Y receiving. Thus, if the key be depressed, as at Y, so that its front contact puts the line to earth, intermittent pulsations of one polarity will go to line, corresponding to the contacts made by the trailer with the segment pertaining to this branch on the right hand side of the distributor at X, while the negative currents, corresponding to the left hand half of the distributor, will be cut out, and the corresponding relay at both stations will be actuated by currents of constant polarity. If, now, the key be reversed, the trailer, on reaching the opposite segment, 5 —, will send an opposite current to line and earth, causing the polarized relay to reverse in accordance with the motions at the key; hence signaling may be effected with a sounder connected in a local circuit as shown. Thus, if the key were closed at both the front and back contacts at the same time, the receiving relays would all vibrate in unison with the synchronizing relay in the line circuit and transmission is effected by cutting out all the positive or all the negative impulses, according to the position of the key, whether on its front or back contact. With a slow speed the contacts connecting any branch to the main line must of course be increased to insure certainty of action; but with a sufficiently high speed few contacts will be required. In the foregoing system, the synchronizing current which is only used as such at two points during each revolution, is made to answer for signaling purposes also.

There are, of course, numerous details incident to such a system that cannot be dealt with in a superficial description. Each operator's circuit being made up of a number of rapid contacts with the main line, each one of the ordinary Morse characters is necessarily made up of a number of pulsations of current, and the serious problem has been to construct a relay that would respond to these broken currents. A single polarized relay has a tendency to leave its contact during the breaks. A number of devices have been made to correct this. Fig. 6 shows by a diagram of circuits a modification of the system of single wire transmission in which superposed currents of high tension are used to actuate receiving apparatus, thus making them independent of the synchronizing current. The key is so arranged as to open and close the primary of an induction coil, the secondary of which

is connected to line. A telephone or similar receiving apparatus arranged to respond to currents of high E. M. F. is connected

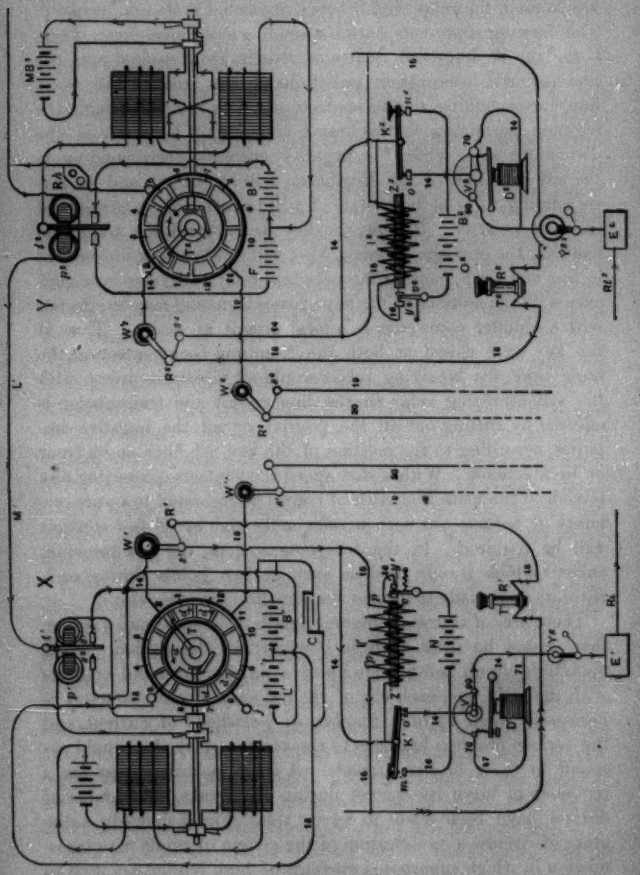

FIG. 6.

with a receiving circuit instead of the relays. With such a system of transmission a higher order of multiplex transmission can be obtained than with ordinary receiving apparatus, and it re-

quires so little current to actuate these instruments that each operator can work a circuit with a far less number of segments. As the trailer makes contact with any particular segment there will be of course two currents sent, due to the make and the break. In Fig. 7 is shown an arrangement by which the first of these is cut out. The primary of the induction coil connected through a separate trailer and series of segments is closed by the

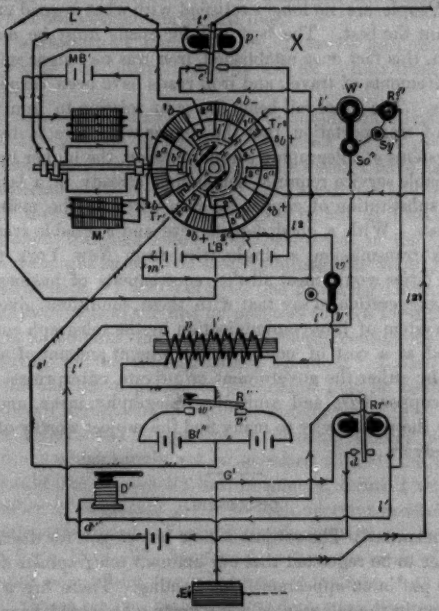

FIG. 7.

key before the trailer connected to the line circuit has reached its segment. The induced current due to the break only, is then transmitted to line. This device is shown in Fig. 7, and as there indicated it has also been made to work polarized relays suitably wound for these high tension currents.

The general subject as a system of telegraphy will be recognized as a rather extensive one for a single paper. I have given the details of a few of the more decisive experiments that have

been made, and I have confined the paper to what has actually been accomplished. With reference to practical results on a line test I shall have more to say at a later day. A technical paper, at its best, is uninteresting, and the present one is already long. In closing, I will answer a pertinent question that may occur to many: "Of what use is a system of multiplex telegraphy?"

The answer is this: We live in an age of industrial advancement. People are no longer satisfied with what is good enough. They want the best. The best rail for roads must be made of steel, and, this fact once established, iron was no longer suited to the requirements of travel, and iron roads have been turned into steel ones. The steel rail bears the same relation to iron in the systems of transportation, that the copper wire does to the iron one in systems of telegraphic communication, the higher rate and more reliable service required demanding already in a large degree the substitution of copper for iron wires on the main lines of business. With a good copper wire and a reliable system of multiplex transmission, a single wire from New York to our principal cities would meet all the requirements of business, and it is no exaggeration to say that with these conditions given, the existing system of intercommunication by the telegraph could be duplicated at a cost of one-tenth the present amount of capital invested by either the government or private enterprises. That is what copper wire and multiplex telegraphy mean, and it is doubtless the reason why so many find the subject worthy of their best endeavors.

DISCUSSION.

THE CHAIRMAN: The subject is now before you for discussion. It is rather to be regretted that our eminent telegraphists did not choose to put in an appearance this evening. There are a number of men in the telegraphic community who would have been able, no doubt, to give us some very interesting details and to ask a great many pertinent questions about this. It certainly is a very interesting subject. It is, perhaps, not too much to say that it is the dawn of future progress in telegraphy. For a long time, telegraph authorities have been of the opinion that the day of monc-telegraphic work is past; that the cost of using the telegraph circuit and maintaining it is so great that we must be able to utilize it and multiply its use by making it answer for more messages than one at the same time. So that in bringing before us this in-

teresting paper, Lieut. Patten has unquestionably given us something which represents the beginning of the future, and you certainly should not lose the opportunity of giving it a thorough discussion. Mr. Pope, you are an old telegrapher, can you not say something on the subject?

MR. R. W. POPE:—I was a telegrapher before we had any of these things. I notice Mr. Prescott here and Mr. Delany. Mr. Delany has done something in this line.

THE CHAIRMAN:—I must beg Mr. Delany's pardon for not having recognized him; I hope he will let us hear from him on this subject.

MR. PATRICK B. DELANY:—I have to compliment Lieut. Patten on the very clear and entertaining discourse he has given on a very interesting subject, and a subject in which I have had some little experience. I do not know that I can ask any questions that will throw any further light upon it, but as I was a telegrapher about the same time that Mr. Pope was in the business, perhaps we might agree upon some inquiries that would be interesting to us both. I would suggest one by asking Lieut. Patten, how many contacts to the line he proposes to give for each Morse circuit, so as to make the circuit sufficiently continuous for the manipulation of the average Morse operator. I didn't catch clearly the number of pulsations per second that he proposed to apply to each branch circuit with his distributors.

LIEUT. PATTEN:—The question is certainly a very pertinent one, and one which cannot yet be answered with all the definiteness I would like to give it; but, in general terms, I would say the number of segments given to each operator necessarily depends upon his speed. I would simply say that we have four contacts for a line. We have made a sounder work with clear action upon an artificial line, of course, at the rate of 30 words a minute. There are two things which determine the number of contacts to be given to any operator in the circumference of a distributor; one is the speed at which the trailer is driven and the other is the amount of time that the trailer rests in contact with the segment. Four contacts give a good reliable result; that would give about 1200 pulsations per minute.

MR. DELANY:—You say that the number of contacts that each operator would have, as a matter of course, depends on the number of revolutions of the distributor. Not necessarily so, because your distributor might have a very slow speed and make several contacts per revolution for each operator.

LIEUT. PATTEN:—I say it depends upon the rate of the trailer in a given unit of time.

MR. DELANY:—If you increase the number of segments in a circuit connected to any operator's instrument, of course, with a very slow motion of your trailer, you would get the same number of contacts. The object of my inquiry was to ascertain the number of contacts that could be given to each operator, and at the same time afford the necessary duration of contact between the distributing trailer and each segment, and enable you to transmit currents over a line of a considerable resistance.

LIEUT. PATTEN:—This is a refinement of the subject which can only be determined by prolonged experiment. I would say that with a few thousand ohms resistance we could get lower than 1-400 or 1-500 part of a second from a single contact.

MR. DELANY:—You say that with 1200 contacts a minute, you get a sufficiently continuous circuit?

LIEUT. PATTEN:—Well, so far as our experiments have indicated, which are on an artificial line.

MR. POPE:—It is my impression that Mr. Delany's experience does not quite coincide with that of Lieut. Patten, in regard to that contact, and I would like to hear what his experience has been as to the number of contacts per second necessary to permit of fast Morse manipulation on long wires.

THE CHAIRMAN:—Mr. Delany, would you kindly give us some of the results of your experience, and I think it would be particularly interesting if you would tell us your experience as to the maximum number of pulsations which can be maintained on a line of a given length, and having a given static capacity; *i. e.* the number of impulses per minute before the static charge interferes to any great extent.

MR. DELANY:—My experience would lead me to believe, not to state it exactly but in a general way, that on a circuit of, say, 100 miles, from New York to Philadelphia, for instance, with perhaps 1,200 to 1,500 ohms resistance, and an iron wire of a capacity, probably, of 1½ or 2 microfarads, that about—I will have to make a little calculation to aid me—that about 500 impulses per second can be transmitted over such a line and received on segments corresponding in position in the circle on a circuit table, provided the trailers and the distributor are in synchronism and allowing a slight moment of time for the retardation of the circuit. If the retardation amounts to one 500th part of a second

then the current sent at one segment in a particular position in the circuit will be transferred to the segment next in the direction of the revolving trailer, and especially so, if the line is not cleared of its static charge. After each impulse has been sent into the line, the charge that is in the line delays the next initial impulse that goes into the line and delivers it in a segment still further removed at the receiving end. I have found that in the operation of what we call good Morse circuits, it requires at least 35 or 36 impulses per second to make a smooth circuit, so that the operator manipulating the key, as is frequently done, at the rate of 12 to 15 times in a second, may transmit to the full measure of his ability, or say, forty words a minute.

THE CHAIRMAN:—Of one polarity?

MR. DELANY:—Of one polarity, or with a reversal of polarities you would get about the same result. With that number of contacts in a second, I have seen more than forty words transmitted for a considerable period of time continuously, say, for half an hour over circuits about as I have described. In order to do that it requires a circuit that varies not more than 1-1000 part of a second. If there is variation in excess of that the currents become so weak that the relays would go out of adjustment or it would be very sensibly felt at the relays at the receiving station.

LIEUT. PATTEN:—Mr. Delany has remarked upon one feature that it might be of interest to mention in connection with this system. I might have put it into the paper, but as I have said, I did not care to go into detail. There is an essential difference between the system as shown here and any system that is founded on the isochronous motion of different moving parts at different stations. For instance, in figure 5, if the apparatus were driven by isochronous machines which were absolutely synchronous, the two trailers would be inclined at exactly the same angle of position at the same instant, and if an electric impulse were sent over the line, and it took any time to reach the other end of the circuit, it is evident that the trailers would have left the position where they were when the impulse started. Whereas, in a system of this character where variable synchronism is maintained we have what you might describe as transmitted synchronism. The trailer is just as much behind the initial one at the receiving station as the time required for the current to traverse the line. These refinements are somewhat delicate, but if there is such a distinction, it is evident that we have more chance of getting the cur-

rent out upon its proper segment in a system that is variable than in one that is isochronous.

I merely bring this point out to show the difference between synchronism independently maintained and that maintained by the circuit. I would like to ask Mr. Delany what E. M. F. he used for the circuit he describes of 100 impulses, working Morse instruments.

MR. DELANY:—About 75 volts we used on the circuit that I referred to. I mark the distinction that the Lieutenant wished to draw between synchronism that is maintained by machines that are not isochronous in their movements, and that of the synchronism shown on the board maintained by transmitted impulses. I would say, that the synchronism with which I have had experience, is also maintained entirely by transmitted impulses, i. e., the synchronism is not maintained in any way by the isochronous method independent of the two machines. One machine is corrected in its movement by impulses transmitted from the other end of the line, the receiving machine is corrected by the transmitting machine, and vice versa. The impulses are sent in opposite directions at different periods of the rotation of the trailer, so that, if the current is sent over segment No. 1, we will say, at station X, and if it takes the time represented by the distance from No. 1 to No. 2 segment, to reach the receiving end, then the correcting impulses which keep the instruments in synchronism will maintain that relation and position of the trailer. We have found it necessary in practice to maintain the instruments in synchronism on corresponding segments where it was necessary or desirable to telegraph in opposite directions simultaneously. Because, if segments at each end of the line are connected to operator A, and one operator is sending to the other, the instruments being in synchronism, the time of the impulses over the line is represented by the time of the trailer from one segment to the other; it will readily be understood that if A be sending to B and the instruments are in synchronism for that condition, then, if B should turn around and send to A, A would not receive the impulses that were sent to him. Consequently, we have to synchronize on corresponding segments if we wish to work in opposite directions simultaneously. If the transmission is always done in one direction, then, as you can readily see, it makes no difference. The time of contact of the segments must correspond to the time of transmission on the line in order to

transmit simultaneously in opposite directions. But where the time on the line is such as to make the transfer more than the margin allowed, (*i. e.*, the variations of the instruments on the face of corresponding segments,) you cannot work in opposite directions simultaneously.

MR. C. J. KINTNER:—I desire to call attention to the fact, which Lieut. Patten appears to have overlooked in his very good description of his apparatus, that it is, so far as I am aware, the first apparatus by which isochronous movement is effected by the apparatus itself. In the old Casselli system, which is perhaps the first isochronous telegraph with which we are familiar, the isochronous movement is brought about by the movement of a pendulum. In Mr. Delany's system, with which we are all familiar, it is done by the harmonic principle. In Lieut. Patten's system, it depends upon the peculiar phases of the alternating current generator and an alternating current motor. It was my good fortune last summer to make a somewhat extended set of tests and experiments of Lieut. Patten's apparatus as to its efficiency and as to the isochronous movements of the apparatus and I found that the apparatus moved uniformly in synchronism, and during the experiments, a very interesting feature came out. We were using six sets of keys at each end of the line and I was testing first with all the keys closed; then one key closed at each end, and successive keys and various numbers of keys, to see that there was absolute synchronism. I discovered that when key No. 1 at section No. 1 was closed at each end, that there was a faint response on section No. 2. I called Lieut. Patten's attention to it for the reason that I could not understand why it was so. At last upon close examination of the brushes I found that they were set slightly at an angle, so that as the brush was passing off section No. 1, it was at the same time also on section No. 2, so that we had a response on the other section, which was an absolute proof of the synchronism of the two sections. Lieut. Patten is making a sketch which will show this. I desire to call attention to the fact that the apparatus is capable of operation, as the Lieutenant has advised me, with an alternating current, in which it is possible, as I understand, to transmit messages over longer lines by reason of the fact that with an alternating current he is able to discharge the line more rapidly.

MR. B. C. BATCHELLER:—I would like to ask how many circuits are worked at one time?

LIEUT. PATTEN:—In answer to that question I have simply to

say that our work was entirely experimental, and I am not at liberty to state what the capacity of the system is, as it has not been tried in such shape that I should be warranted in stating it.

THE CHAIRMAN:—There is one practical question, I think, which follows from the observations made by Mr. Delany, and while he was speaking I rather misapprehended his statement. Mr. Delany states that on each pair of instruments you have some 35 pulsations per second, in order to get Morse readings. Now it so happens that in Mr. Delany's system he has the control of making these impulses of either polarity, because the battery is used at either end of the line and can connect either pole to the ground. If I understand the Lieutenant's system rightly, the polarity of the impulses is alternating necessarily. Consequently, out of 35 impulses given to the pair of instruments, 17 of them will be of one polarity and the rest of them another. The question then occurs whether that number would be sufficient, or whether in reality it would not be necessary for him to have 35 of each polarity in order to effect good Morse readings?

LIEUT. PATTEN:—I have to say in reply that with our artificial line work, which is all we have done up to date, we have found that a far less number than 35 gives us very good results. In fact, the sounder acts very clear and sharp and is up to a speed of transmission of some thirty words a minute, with some 15 pulsations per second, I should judge as the average amount. It is impossible to tell accurately what number of pulsations there might be within 5 or 10. It varies from 15 to 25, I should think.

MR. FRANCIS B. CROCKER:—Lieut. Patten has spoken several times of variable synchronism. The expression is perfectly correct, but it sounds rather startling to the ordinary hearer, because one's idea naturally is that synchronism is constant. He also makes a distinction between synchronism and isochronism. There is a distinction, of course, but he did not explain it very fully. Synchronism means, for example, that the two instruments revolve together whether fast or slow, whereas isochronism means that they revolve together at a certain speed. With a variable synchronism one may start off two instruments revolving together at 100 revolutions and then raise the speed of both at the same time to 1000 revolutions, but they still run synchronously all the time, just as the two driving wheels of a locomotive which are attached to the same axle, of course revolve synchronously; *i. e.* at the same speed, but they may revolve at 100 or 1000 revolutions a minute. It is in this way that we have a vari-

able synchronism. I considered that the confusion which might arise from this was worth pointing out. The Lieutenant passed over it quite rapidly, because, of course, he is so very familiar with the subject.

THE CHAIRMAN:—That is a very important distinction that Mr. Crocker has made. It would appear that Lieut. Patten's system works both synchronously and isochronously.

LIEUT. PATTEN:—Mr. Crocker's distinction is quite correct. I had intended to bring it out, but perhaps did not do so quite clearly enough, but the distinction he makes is in further illustration of my paper, and I thank him. In working the instruments, we try to drive them at as uniform a rate as possible. I brought out this idea of variable synchronism as a distinguishing feature of the system, not as one that would necessarily be used to a large extent. If machines are running at a good speed, a uniform 100 or 200 revolutions per minute, they are isochronous machines, and of course synchronous also. But if their speed is changed, they are no longer isochronous for the time being, they are simply synchronous.

MR. E. C. DAVIDSON:—With your permission I should like to refer to one point. Mr. Kintner has suggested that the Delany system was based on a harmonic principle. I do not so understand it. I waited for some one to inquire into that, but as no one has done so, I will take the liberty of speaking of it. As I understand it, no question of harmonics is involved. The circuit breaker is employed to control the rotation of the motor at either end of the line. That circuit breaker, it is true, may be a fork, it may be a rotating wheel; that is entirely immaterial. There is no question of harmony about it. As the circuit breaker makes and breaks the circuit at the end of the line, what is after all a small electric motor is rotated, that is, the passage of the pole of a disc or armature in front of a magnet coincides with the break in the circuit; that produces the rotation. Now the character of the impulse sent from one station to another merely modifies the circuit breaker; it slows it or accelerates it, and the two instruments are thus tied together. I do not understand that it is at all analogous to a harmonic telegraph.

THE CHAIRMAN:—I think the distinction is quite right to a certain extent, but probably the word harmonic should have been changed to rhythmic, The action of the instrument in Mr. Delany's system has reference more to maintaining a certain rhythm in the pulsations than to their harmony.

MR. KINTNER:—I accept the suggestion, I simply wanted to convey the idea that in Mr. Delany's system, like Casselli's, the synchronism was maintained by an extraneous apparatus, an apparatus extraneous to the motors themselves. Of course, we are all familiar with Mr. Delany's inventions and know exactly what they do. We are aware that his inventions have wrought a wonderful improvement in multiplex telegraphy, and most of us, I presume, have seen them in operation. They were in operation here at the Institute some years ago, and there is no doubt about their wonderful success. I had no idea of calling them harmonic telegraphs, I merely wanted to bring out that distinction that they were controlled by extraneous means.

MR. DELANY:—I beg to assure Mr. Kintner that there is no discord produced by his allusion to harmonics.

THE CHAIRMAN:—We have with us this evening a gentleman who knows something of multiplex telegraphy in Europe, our friend Mr. Abdank-Abakanowicz.

MR. DELANY:—If you will pardon me one moment, when Mr. Davidson referred to the making and breaking apparatus, I was going to make the description a little more clear, perhaps, by stating that it was an automatic circuit breaker originally, a tuning fork in connection with what is known as the phonic wheel; that is, perhaps, where Mr. Kintner inadvertently got his idea of harmony. My synchronous and my multiplex telegraph are based primarily on the very ingenious contrivances of Mr. Paul La Cour, his automatic circuit breaker in connection with a phonic wheel, an instrument that is moved by very fine increments. It moves in a little space at a time, and consequently has no opportunity for very wide variation before it is brought again to the centre of attraction by those recording impulses.

MR. ABDANK stated that he had never made a special study of telegraphy, but he had examined with great interest the synchronous devices of Lieut. Patten, and was impressed especially with the solidity and great power of the motor running in synchronism.

THE CHAIRMAN:—There is a great deal of interest to be said on this subject, but as the time seems to be passing away, I shall have to pass on to the consideration of the next topic, which is the notes on Mr. Acheson's paper, by Messrs. C. T. Child and Jo. Stanford Brown.

MR. BROWN then read the following paper:

LIGHTNING ARRESTERS AND THE PHOTOGRAPHIC STUDY OF SELF-INDUCTION.

NOTES ON MR. E. G. ACHESON'S PAPER, BY JOS. STANFORD BROWN AND CHARLES T. CHILD.

Having been requested upon very short notice to re-open the discussion on the highly interesting paper on "Lightning Arresters and the Photographic Study of Self-Induction," presented at the Institute meeting held January 8th, the following hasty notes and queries are with diffidence offered for consideration. Truth alone is sought, and it is a matter of regret if any criticism should even tend to disparage the worthy endeavors of one who has so fearlessly grappled a problem fraught with such interest alike to both theorist and practical electrician.

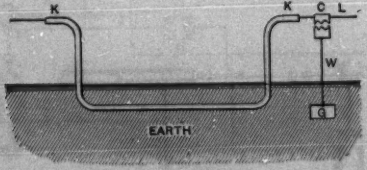

FIG. 1.

After careful reading it would seem as if the subject might be approached with advantage from more than one standpoint, and that even somewhat different conclusions were deducible simply by re-arrangement of the experimental data. We have given, a submarine or subterranean cable, to each end of which at its junction with the main line a lightning arrester is connected in the most approved manner, Fig. 1, to determine why, in spite of these precautions, the cable is not infrequently punctured when an "electrical discharge" enters the overhead system.

For experimental purposes this has been reproduced in miniature, as shown in Figs. 2, 2*a*, 2*b* and 2*c*, by the line L entering the cable K at the point P, to which point is attached the lightning

arrester C grounded through the wire W. The "electrical discharge" arises from the Leyden jar J, charged from the Holtz machine M N, and strikes the line at A. The outside of J will represent the earth, to which the ground wire W and the "earthing" of the cable, represented by E, "twisted a single turn" (*Western Electrician*, IV, 47) about the cable, is connected. Is it not possible, then, to throw Fig. 2 of the previous paper into the form Fig. 2*a* for the purpose of drawing attention more di-

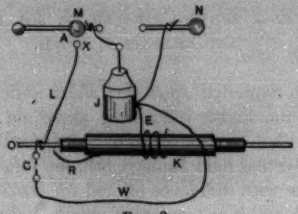

FIG. 2.

A and C constant.
B and W variable.
Capacity of J—.0025 m. f.
" " M and N not given.

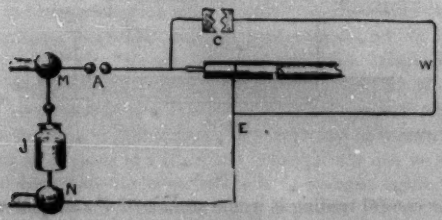

FIG. 2 *a*.
Fig. 2 redrawn.
Case of a cable protected by a lightning arrester.

rectly to the relation of the circuits involved? The discharge, or momentary current, from the jar J entering at A traverses the line L to the point P, where two paths are offered; one, through the lightning arrester C to earth E; a second, in practice, by puncturing the cable insulation. C now being made but a fraction of the insulation thickness, and W a short, thick copper wire, it was found that the cable was still frequently punctured at times when a spark appeared at C, and that the length of W appeared to enter

the effect equally with the space variation of C. *No part of the effect*, it will be noted, *is attributed to the action of the cable as a condenser.*

The problem is now changed to that shown in Figs. 3 and 3a, presenting a divided circuit with the lightning arrester at a constant distance of .02 inch, and the earth wire W long, compared with that connecting the variable B space with the same earth point. May not this arrangement of split circuit with an air space in each branch be looked upon as the general case for which Dr. Lodge's "alternative path" represents the condition of mak-

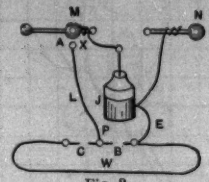

FIG. 3.

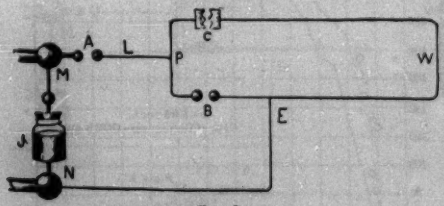

FIG. 3 *a*.

Fig. 3 redrawn.
A constant—0.286."
C " —0.020."
B variable.
W, of copper, .062" diameter, with variable length.

ing one of the air spaces zero? What then is the relative efficacy of changing the length of W and the distance of the C points *to prevent* a spark at B which represents the puncturing of the cable insulation, providing the B points are held equivalent to the long length of cable wire at any point of which puncturing may occur?

To decide this with A and C fixed at .286 and .02 inch, respectively, B was varied with W to keep the spark ratio of B to A constant at one to ten. Then removing C (*i. e.*, for C equals zero) the operation was repeated, and a comparison of these results is shown in the curve, Plate A. Instead of this procedure, should not B

have been made non-sparking for C and A fixed, and W varied until a spark was got at B, and then W left constant for variations of C up to a point where B would spark?

That with the connections of Fig. 4 and W equal 20 feet a spark should pass at B of over ¼ inch in length might perhaps have been expected from Dr. Lodge's results (London *Electrician*, XXI, 815), shown here in Fig. 4b, when there is an alternative

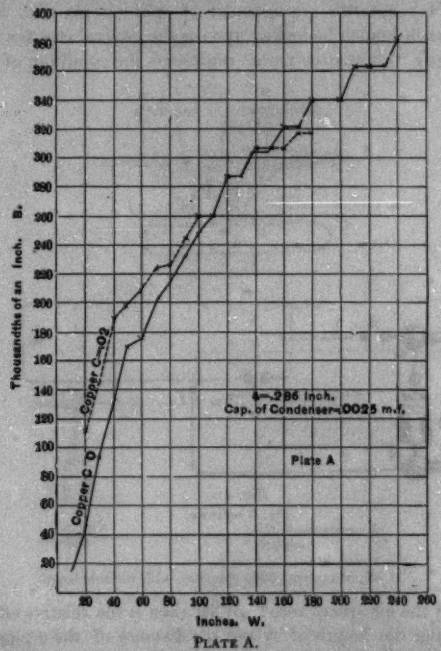

PLATE A.

path in which the self-induction of W (Lodge's L° loop) comes into play. True, Fig. 4 is not an "alternative path" of necessity, for the B points may be moved out of the sparking distance.

W is now supposed "electrified" by the charge across A. The "inverse extra current" of making, simply cuts from the charging current; but the "direct extra current" of breaking, *i.e.*, charging impulse cessation, acts as its continuation but at a higher

potential (Ganot, 7th edition, 776). This extra current then is running towards E and would naturally be supposed to equalize on the same path as the current generating it. It might therefore be expected to dissipate on reaching earth; the circuit is, however, claimed to close itself through P W E B, or, more clearly, around the closed circle of the L° loop, Fig 4b.

It would be of interest to some in this connection to know how it was ascertained that the instantaneous time duration of the extra current is shorter than that of the charging current; for if

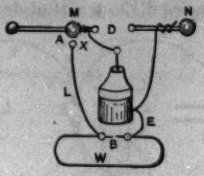

FIG. 4.

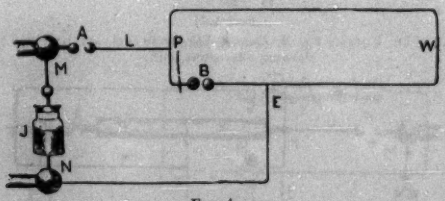

FIG. 4 *a*.

Fig. 4 redrawn.
A constant—0.286."
B " —0.333."
C removed.
W—20 feet of copper wire, .053" diameter.

this be assumed, because of the known higher electromotive force of the former, the argument would seem to be in a circle.

On the assumption that the extra current dissipates through B, and not in the earth, it is argued that shortening W would tend to decrease this tendency to puncture the cable. To test this we have B equal the insulation thickness, C and W removed, and we get Fig. 2b if the C W circuit be supposed omitted. "With this arrangement it was not found possible to puncture the cable." May not this be regarded simply as a safety short circuit for our cable considered as a Leyden jar? And what is this but a working case of a cable effectually protected by a lightning arrester

B? While the electrostatic capacity of a "short piece of cable" may be negligible compared with that of twenty feet of No. 16 B. & S. wire, it is perhaps doubtful if the capacity of a commercial cable could be so regarded in comparison with that of the ground wire from the lightning arrester.

It is not altogether plain how the direct extra current is an effect of Faraday's electro-tonic state when Faraday says (*Researches*, I, 16): "This state is altogether the effect of induction exerted, and ceases as soon as the inducing force is removed. And Jaquez ("Dictionaire d'Electricité et de Magnetisme," 1887,

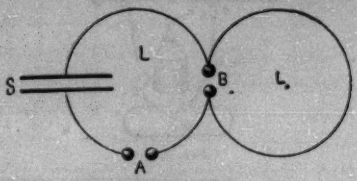

FIG. 4 *b*

Cut of Dr. Lodge's Fig. 2, *London Electrician* (vol. xxi, page 815.) showing alternative path.

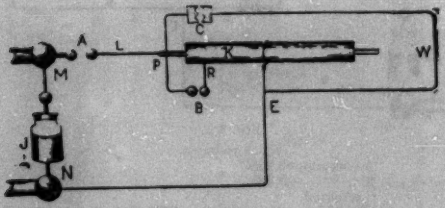

FIG. 2 *b*.

p. 138) defines it as "the state of the conductor during the interval of time which separates the appearance and disappearance of an induction current." Maxwell, by the way ["Electricity and Magnetism" (2d ed.) II, 174], calls it "the fundamental quantity in the theory of electro-magnetism." Would it not be possible to regard it as an electro-magnetic potential stored in the wire ready to show itself as direct extra current? With the citations quoted above, how can this electro-tonic state exist *before* the electrifying current is discharged into the circuit?

Fig. 5, 5a, 6 and 6a illustrate effects of different kinds of work introduced into the circuit. For references see Fleming's "Short

Lectures to Electrical Artisans," pp. 44, 45, and Ganot, 7 ed., 776; Maxwell, "Electricity and Magnetism," 2d ed., II, 211; Dove, Poggendorff's *Annalen*, Vol. XLIX, 1840, etc.

The methods used in the photographic part of the investigation would seem to cast some doubt on the results claimed. The effects noted deal chiefly with the prolongation or diminution of the current wave of the jar discharge by the secohmic resistance cut into the circuit. Might not a large element of uncertainty be introduced in the plates by the different degrees of illuminating power possessed by the sparks and by the irradiation of the plate?

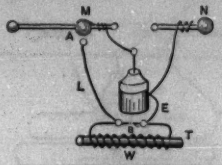

FIG. 5.
T—0.25″ diameter.

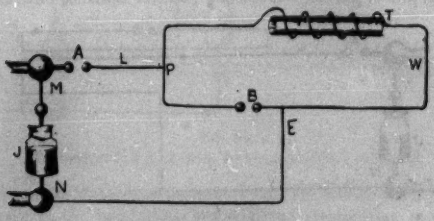

FIG. 5 *a*.
Fig. 5 redrawn.

In the cases when the discharges are through 76 and 20 inches of the same wire, respectively, hardly any difference appears in the spark. Is it not possible that the illuminating power of the quick bright spark through the short wire was so much greater than that of the necessarily more extended and consequently fainter spark through the long wire as to make the effect practically the same?

In the experiment in which two spark intervals are included in the circuit, as against one, formerly, it was found that the spark was materially lengthened. This might be expected considering

the practically infinite resistance of the second air space which is introduced. The spark length, too, was found inversely proportional to any form of work introduced in the ground wire circuit. Possibly the photography of spark duration is not altogether the best method of measuring them. It is not yet by any means certain that a sensitive plate is equally affected by small equal time intervals at the beginning and end of the exposure, nor is it improbable that with sharp edged holes moving at an extremely high velocity some diffraction phenomena might intervene that would introduce serious errors in the photograph. It is, besides, very difficult to measure the faint trails of light left by the spark.

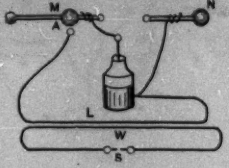

FIG. 6.

Length of parallel portions of circuits, 35″; distance separating them, 0.052.″

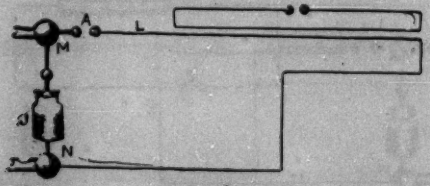

FIG. 6 *a*.

Fig. 6 redrawn.

On the negative they are practically invisible and in the prints their extreme delicacy and the fact that they fade away into the surrounding blackness without any sharp line of demarcation renders them almost impossible of measurement. On these grounds the measured spark distances of the first part of the article are probably more trustworthy as a basis for theory than the photographic results of the second part.

Returning to our original problem, why may not the cable, acting as a condenser, puncture itself in discharging, it having been charged by the current from A, Fig. 2c, which, meeting the lightning arrester, backs up its potential until able to strike across and

thus to ground? This discharge occurs simultaneously with the spark at c.

If a wave of current be pictured passing along a linear conductor, it would probably appear something like Fig. 7, its front lengthened out by the self-induction effect of the cable, while the tension in the rear part is raised by the direct extra current. This

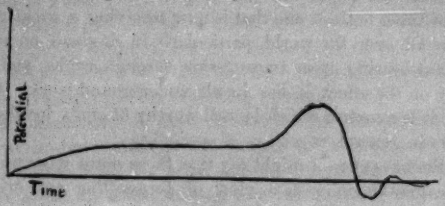

FIG. 7.
Form of current wave

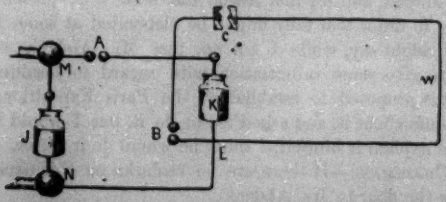

FIG. 2 *c*.
Equivalent to Fig. 2, with cable replaced by a condenser.

high potential wave crest moves along the cable, until finding a weak spot in the insulation, it discharges rather than keeps up its strength with the impeding current ahead of it.

It is hoped to be able to present at some future meeting the results of certain experiments delayed so far by pressure of professional engagements.

DISCUSSION.

MR. BROWN:—These points are not meant to be anything in the nature of a discussion of the subject, they are merely brought up as hastily considered, and we hope that some of the gentlemen present may find them worthy of discussion. My friend, Mr. Child, is here, and will be glad to discuss any points, I am sure.

THE CHAIRMAN:—Gentlemen, these interesting notes are now

before you for discussion. It is to be regretted that Mr. Acheson is not here, because he is so familiar with the subject that he would have been able to say something of interest in the discussion; however, as the authors promise us a paper at a future meeting, we feel quite certain from the foretaste that they now give us, that the paper will be of great interest. The subject matter of these notes is one that is now receiving a great deal of attention all over the world, particularly in England, on account of its great bearing upon transmission through cables, and more remotely on the effect it has in all underground work. Consequently, it is a matter which is well worthy of study by electrical engineers in general, as well as of specialists.

THE SECRETARY:—I might say that these notes were prepared by these gentlemen with a view of forestalling any criticism which might arise. We felt in talking it over, that if the paper was to be criticised, it would be well to have it done at home, and not abroad, and for that reason the notes were presented in this way, in order that they might be elaborated at some future time. I might say, while I am up, that Mr. Abdank will be pleased to give some information with regard to headquarters which it is proposed to establish at the Paris Exposition. He spoke to me about it, and asked me to do it, but I would like to have him explain it himself, I think he would do it better.

THE CHAIRMAN:—If there are no remarks on this paper, we will give the floor to Mr. Abdank.

MR. ABDANK:—We have next year an exposition in Paris, as you know, in which there will be a special section devoted to electricity, and I am in charge of that section for the United States. I have collected a very nice exhibit, and I suggested having in the American section headquarters for the electricians of the United States. We will have there a collection of all the electrical papers published in the United States and the books published here, and then we will have a special attendant there, who will have in charge a register, where the members of the electrical societies can come and find necessary information, and I would suggest that the Institute here give us for the Exposition a collection of the proceedings for its headquarters, and a book wherein the members of the society arriving in Paris may inscribe their names.

THE CHAIRMAN:—We are very grateful for these remarks; the plan is one that every electrician will appreciate who visits the Exposition.

MR. ABDANK:—I forgot one thing, we have a special box for the reception of letters addressed to members, and any member intending to visit the Exposition can have his letters delivered there by simply having them addressed to the Paris Exposition, American Section, Box Electric. Our office boy will put all the letters in order, and we will distribute them to the members arriving in Paris.

THE SECRETARY:—The Council, as you are probably aware, has arranged to supply a set of Transactions to the Exposition, and I presume they will act on Mr. Abdank's suggestion and furnish a register for the recording of names.

THE CHAIRMAN:—I have no doubt that the subject will be taken up in due course by the proper authorities, and that our secretary here, with his usual eye to everything relating to the welfare of the Institute, will see that the matter is attended to in the proper manner.

Adjourned.

[*Communicated.*]

LIGHTNING ARRESTERS AND THE PHOTOGRAPHIC STUDY OF SELF-INDUCTION.

A Reply to the Notes of Messrs. Jo. Stanford Brown and Chas. T. Child.

BY E. G. ACHESON.

A theory that cannot withstand the attacks incident to a general discussion, should be abandoned at the earliest moment. It is only by careful, exhaustive study, experimentation and discussion, that any theory can be proven worthy of acceptance. While our thoughts, energies and moneys are being directed to and expended for the adaptation of old, well-known principles, and the improvement of the various devices embodying those principles, it is wise to keep up a constant, restless, untiring search for new principles.

It was with such sentiments in mind that I formerly appeared before you; it is with such sentiments that I now approach this subject.

The reverence that all students of science should, and I am sure, do, feel for the opinions and theories of those who have in past years labored in our chosen field of research, ought not to be of such an all-absorbing character as to debar them from striving to add to and expand those theories; and peradventure, should occasion arise, abandon and throw aside those opinions and theories held sacred by our predecessors.

The discussion on my paper, entitled: "Lightning Arresters and the Photographic Study of Self-Induction," was reopened February 12th, 1889, by Notes from Mr. Jo. Stanford Brown and Mr. Charles T. Child. I regret that my time has been so much occupied during the last few months, that I have been unable to continue my investigations on the subject under discussion. Regrets are, however, useless, and I will, therefore, deal with the question as best I can with the material at hand.

In handling the subject, permit me to first quote each question or point as expressed in the "Notes," and then present such explanations or arguments as I may find possible or convenient.

QUOTATION:—"After careful reading it would seem as if the subject might be approached with advantage from more than one

standpoint, and that even somewhat different conclusions were deducible, simply by rearrangement of the experimental data. We have given, a submarine or subterranean cable, to each end of which, at its junction with the main line, a lightning arrester is connected in the most approved manner, Fig. 1; to determine why, in spite of these precautions, the cable is not infrequently punctured when an "electrical discharge" enters the overhead system. For experimental purposes this has been produced in miniature, as shown in Fig. 2, 2*a*, 2*b*, and 2*c* * * *"

REPLY:—Figs. 2*a*, 2*b* and 2*c* have been introduced by the Authors of the "Notes," and while Figs. 2*a* and 2*b* are a close analogy to Fig. 2 and may be used to represent the case as presented in my paper, I make exceptions to Fig. 2*c*, for a condenser as there illustrated, can not be substituted for an elongated condenser as is obtained with a cable (see p. 143.)

QUOTATION:—"C now being made but a fraction of the insulation thickness, and w a short, thick copper wire, it was found that the cable was still frequently punctured at times when a spark appeared at c, and that the length of w appeared to enter the effect equally with the space variation of c."

REPLY:—Part of this quotation contains language similar to that used in my paper, as do various other portions of the "Notes" but as no quotation marks are used, I can not, of a certainty, tell whether the authors made any of these experiments or whether they are simply restating the experiments and results obtained by me. If the latter be the case I beg to correct the results, as stated to have been obtained, in the last quotation. I found the wire w appeared to have as much influence on the results as the space c. The space c was always of a uniform length, hence no space variation of c occurred.

QUOTATION:—"What, then, is the relative efficacy of changing the length of w and the distance of the c points (Figs. 3 and 3*a*), to prevent a spark at B * * *"

REPLY:—Owing to the fact that the authors then proceed to describe one set of my experiments and refer to the curves plotted from the results, and then suggest other, and I presume in their opinion, better, methods of determining this question; owing, I say, to these facts I am led to believe that they have not been as careful in reading my paper, or at least have not understood it as fully as might have been.

The question they propound is not the one I had presented to me. Reading from my paper, "A few more experiments also

demonstrated that the wire w had apparently as much influence on the results as the space c, and consequently it became necessary to analyze the combination more completely to determine the relative values of c and w." To determine these values I did the simplest thing possible, viz: I first determined the value of w without c, and next introduced c and measured their united values.

Again, the object was not to determine their efficiency as *preventives* of the spark B, but rather their values as *producers* of that spark.

QUOTATION:—"That with the connections of Fig. 4 and w equal 20 feet, a spark should pass at B of over $\frac{1}{4}$ inch in length, might perhaps have been expected from Dr. Lodge's results (London Electrician, XXI, 815), * * * True; Fig. 4 is not an 'alternative path' of necessity, for the B points may be moved out of the sparking distance."

REPLY:—The obtaining of this spark $\frac{1}{4}$ of an inch in length, did not surprise me in the least, as I *did* expect it, for I had read of Dr. Lodge's experiments prior to that date. My expectations were, however, excited by his actual experimental results, and not by his theories and formulæ, as set forth in the above reference, and which were constructed to account for his experimental results.

When I remarked in my original paper, that the simple assertion that B and w were "alternative paths" did not, however, make them such; the peculiar idea contained in the latter part of the last quotation from the "Notes" had not occurred to me, excepting as it applied to the current as originally discharged from the jar J; if, however, I properly interpret the meaning in these "Notes," it is there suggested that they (the B points) might be separated to such a distance as to prevent any sparking whatever. But unfortunately they would then cease to stand as 1 to 10 compared with w, and those are the conditions we are considering, hence I fear it will be necessary to drop this suggestion regardless of its extreme originality.

"QUOTATION:—"W is now supposed 'electrified' by the charge across A."

REPLY:—I am not aware that I assumed that to be the case; but rather that w became electrified by the energy discharged from the jar J.

QUOTATION:—"The 'inverse extra current' of making simply cuts from the charging current; but the 'direct extra current' of breaking, *i. e.*, charging impulse cessation, acts as its continuation, but at a higher potential. (Ganot, 7th edition, 766)."

REPLY:—I do not believe I made any statement contrary to the above. The law is a well known, universally accepted one, and scarcely needs the support of any special authority.

QUOTATION:—"This extra current then is running towards E and would naturally be supposed to equalize on the same path as the current generating it. It might, therefore, be expected to dissipate on reaching earth."

REPLY:—With the kind permission of the authors of the "Notes," I would like to ask them what they mean by the term "equalize," and how they suppose "dissipation" takes place?

While it is well known that a charge of energy in a Leyden jar will become dissipated if left to itself and without any specially prepared discharging circuit, such a process cannot be considered in connection with the phenomena under discussion. The authors cite their authority for the generation of a current in the circuit and its flow or discharge into the jar; now, how they expect it to be dissipated I cannot see from their statement. The very name of this current—the extra current—defines it as existing distinct from the original, hence they cannot expect the original current to neutralize it, for it is the product of that current, and for it to neutralize itself requires it to either short circuit its own extremities or discharge back over the same path in which it was formed or generated.

QUOTATION:—"It would be of interest to some in this connection to know how it was ascertained that the instantaneous time duration of the extra current is shorter than that of the charging current."

REPLY:—A careful re-reading of my paper fails to bring to light any assertion that this was in any manner a demonstrated fact. I do not believe I referred to this in any other way than interrogatively—not being desirous to force my opinions, that were of a purely theoretical nature. The point being now raised however, I will take advantage of this opportunity to express my ideas more freely. It is not to be supposed that the authors of the "Notes" believe otherwise than that the "direct extra current" is less in energy *under ordinary conditions*, than the original current. They have given authority for their belief that it

is of higher electromotive force. Their entire argument is on the basis that it traverses the same circuit as the original current; and hence it cannot meet a greater resistance, but possibly, everything being considered, including the fact that the circuit has already been *electrified* by the original current, the resistance may in reality be less in value than that opposed to the primary current. With these conditions given, are the authors prepared to assume that the extra current is even of the same duration as the original?

QUOTATION.—"On the assumption that the extra current dissipates through B, and not in the earth, it is argued that shortening w would tend to decrease this tendency to puncture the cable.* * * May not this be regarded simply as a safety short circuit for our cable considered as a Leyden jar? And what is this but a working case of a cable effectually protected by a lightning arrester B."

REPLY:—Once more I ask the authors of the "Notes" how they would expect the energy conveyed or represented in the extra current, to become dissipated in the earth (in this case the jar) in the infinitesimal intervals of time with which we are dealing. It would be interesting to know how they account for the oscillatory discharge of a Leyden jar, or do they disbelieve that oscillations occur? I will venture to express an opinion on this subject. The original current discharged from the jar does its equivalent of work in the circuit, and ceases to exist as current. The work performed appears as heat, light (under some conditions) and a distorting of the lines of energy which were originally within the circuit. The last work mentioned is of such a character that it causes another current, called the extra or self-induced current to be formed. The energy constituting this self-induced current is not localized into one or more places as was that forming the original current when contained on the surfaces of the jar; but it is distributed over or throughout the entire circuit. When such a circuit is "short circuited" surely the energy will be delivered more quickly, than would be the case with the energy in the jar, for there it has to traverse the entire circuit. Where no short circuiting occurs and the connections remain to the jar, the self-induced current will discharge into it.

Returning once more to the subject, I must say that under the conditions of my experiments, I cannot admit that the wire B, as shown in Fig. 2, acts simply as a safety short circuit for the cable

considered as a condenser; but that it is a working case of a cable effectually protected by a lightning arrester I heartily agree; indeed, the major portion of my experiments were performed and my paper prepared to demonstrate and emphasize that fact.

QUOTATION:—"It is not altogether plain how the direct extra current is an effect of Faraday's electro-tonic state, when Faraday says (Researches 1, 16.): 'This state is altogether the effect of induction exerted, and ceases as soon as the inducing force is removed.'"

REPLY:—The theory that the extra current, is due to the peculiar state of the circuit prior to the passage of the inducing current, was formed by me a long time ago, and was set forth in an article published in the *Electrical World*, Feb. 25th, 1888. The authors of the "Notes" are correct in so far as they go, and perhaps they are wholly so, on this point; but it is true that Faraday was never perfectly clear in his opinion as to this electro-tonic state. After having formed the opinion as above expressed in the quotation, he changed his ideas and considered there was no necessity for assuming the existence of this prior state. (Researches Vol. I, 66, 69.) Again, later on he revives the idea. (Researches, Vol. III, 367, 420.)

I do not deny, but rather confess to having attempted to add a little to Faraday's idea on this subject, for while he considered the state due to a peculiar action of the magnetic lines of force emanating from some external source, and that this state in conjunction with motion produced an electric current, I have gone back one step further and assumed a peculiar state prior to the influence of the external magnetic lines of force, and that it is this prior condition of the circuit that is the true cause of an electric current being generated when the circuit is forced to move across external lines of magnetic force. I justify my action in terming this prior state the electro-tonic state, by the fact that Faraday has, so far as I can learn, left it in more or less uncertainty, and also from these words of his. (Researches, Vol. III, 420.) "Again and again the idea of an *electro-tonic* state has been forced on my mind; such a state would coincide and become identified with that which would then constitute the physical lines of magnetic force. Another consideration tends in the same direction. I formerly remarked that the magnetic equivalent to *static* electricity was not known * * *"

If an error has been committed in thus venturing to trespass, I can only refer to the opening remarks of this communication, and add that the feelings that have inspired me in this work are there set forth.

As a passing remark I would say that I saw it stated in print, within the past few weeks, that this theory was old and contained nothing new. Evidently some one is wrong.

QUOTATION:—"Figs. 5, 5*a*, 6 and 6*a* illustrate effects of different kinds of work introduced into the circuit."

REPLY:—The authors then give a list of references to support this statement, I presume; but as I do not possess nor can I have access to any one of the volumes referred to, I will take it for granted they have sustained their statement, and which, by the way, agrees exactly with my own opinions, and which I believe I stated very clearly in my original communication. Without being able to see their references, however, I am at present unable to know whether they have referred to work producing similar results under similar conditions or not; but I am persuaded to think they have not.

QUOTATION:—"The methods used in the photographic part of the investigation would seem to cast some doubt on the result claimed."

REPLY:—That there is a possibility of the results obtained with the photographic apparatus having a limited value, owing to the uncertainty of uniformity in the speed of the disc and in other portions of the work, cannot be denied.

The results obtained do, nevertheless, correspond closely, not to say exactly, with those of the former portion of the investigations, when studied by the theories advanced. There are so many chances of error in this portion of the work that I would not myself refer to it, had not the authors of the "Notes" reviewed it and suggested various other ways and means for accounting for the peculiarities of the results as obtained.

QUOTATION:—"In the case where the discharges are through 76 feet and 20 inches of the same wire, respectively, hardly any difference appears in the spark. Is it not possible that the illuminating power of the quick, bright spark through the short wire was so much greater than that of the necessarily more extended and consequently fainter spark through the long wire as to make the effect practically the same?"

REPLY :—The duration of these two sparks I found to be about the same; but with the shorter wire more work was done in the air space where the spark was produced. The fact that the spark with the short wire is brighter is an evidence of the increased work done at that point. This increase of work was indicated in the photograph by a heavier "ghost;" while the equality of their durations was shown by equal lengthed "ghosts." The simple fact of a spark being brighter, would not, I think, produce an elongation of its image through a rapidly moving aperture.

QUOTATION :—"In the experiment in which two spark intervals are included in the circuit, as against one formerly, it was found that the spark was materially lengthened. This might be expected considering the practically infinite resistance of the second air space which is introduced."

REPLY :—I was under the impression, as indeed, I thought all others were who had been closely studying the recent advances in this line, that the question of length of circuit was of more importance in point of time, than resistance, and perhaps more especially so when the resistance was formed by an air space. Again, how can the authors account for the fact of my having obtained so small a time interval with 76 feet of wire in circuit with the air space A, when the B points were in adjustment, for they will find by referring to my paper that the second air space, which was introduced to replace the wire, was of the same length as space A. At this writing I desired to refer to the negatives and examine them, but unfortunately while all the others remain, the one produced with the two spaces in circuit, is missing, and I will not attempt to do what the authors seem to have considered doing, viz: Measure the lengths of the "ghosts" on the prints from the cuts. That they should have found the "ghosts" or trails, on the negatives practically invisible is rather strange, and I believe had I had the pleasure of being present at the time of their examination I might have been of service to them, for I have found not one who experienced difficulty in seeing the "ghosts," while none could define their limits.

QUOTATION :—"If a wave of current be pictured passing along a linear conductor, it would probably appear something like Fig. 7, its front lengthened out by the self induction effect of the cable, while the tension in the rear part is raised by the direct extra current. This high potential wave crest moves along the

cable until, finding a weak spot in the insulation, it discharges rather than keep up its strength with the impeding current ahead of it."

REPLY :—We have in this quotation and the accompanying figure all of the elements necessary either to substantiate the theory I have been advancing or else prove its utter worthlessness. The difficulty, of course, is in obtaining a correct interpretation.

May I ask how the authors determined that the direct extra current, occupied a shorter interval of time, as shown in the figure, than that of the original current? A fuller explanation of the discharging, through the insulation, of the high potential wave crest of the extra current would be interesting. Is it supposed to break through and rush out, like water through a bung-hole? We are here dealing with a complete electrical current, generated within the wire and having its high and low potentials within the wire. In accordance with the accepted theories, a current is supposed to discharge itself into or through a closed circuit, and this would necessitate both ends of the wave breaking through the insulation, if the insulation be broken at all. Perhaps this is the way in which they assume dissipation occurs. It is evident that the authors of the "Notes" are here confounding self-induced currents with static discharges.

It is probable that the gradual increase of the current as shown in Fig. 7, is more or less a correct representation of the facts.

What causes this cutting away of the earlier portion of the current wave? The authors say correctly, that it is produced by the self-induction effect of the conductor.

It is due to an inverse current having been raised in the path of the charging current. The work of producing or creating this current constitutes the momentary resistance that has been termed *impedance* by Mr. Oliver Heaviside, and it is this resistance that Dr. Lodge assumes bars the path of the discharging current by the way of the wire w and causes it to take the path offered by the B points. (Fig. 4.)

For the *impedance* of a wire to offer a resistance, or rather, for the *impedance* to exist prior to the expenditure of more or less of the current that it impedes, is exceedingly difficult, in fact impossible, to comprehend; for the existence of the resistance would be wholly unknown, did not the current energy exert itself against it; but the moment the first portion of the current wave

meets and, speaking figuratively, combats with the resisting force, that portion of the current dies, but in dying it overcomes as much of the opposing resistance as is measured by its own energy; in fact they die together. This is followed by the overcoming of yet another portion of the *impedance* by another portion of the current energy, and so on to the complete annihilation of the total *impedance*.

But this process requires the loss of our original current energy; and if this be the case, and it must be so in order that the *impedance* have even an existence, how are we to discharge this energy across the B points, in the manner described by Prof. Lodge? Perhaps it may be said that it is a surplus quantity that was not required for this formation of *impedance* that jumped the space at B; but this can hardly be so, for any energy remaining after the down-fall of the *impedance*, would have an open road through the low resisting wire.

Out of the dead body of the *impedance*, comes forth the energy expended at the B points.

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Proposed Pacific Cables. *Lond. Elec. Engr.*, Nov. 23, p. 428.

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Cable-Testing—Copper and Dielectric Resistance. (Corr.) C. Bright. *Lond. Elecn.*, Dec. 7, p. 148.

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THE TELEPHONE, ETC.

A Stetho-Telephone. *Md. Lt. & Ht.*, Dec. 13, p. 662. (Lowth.)

The Throat Telephone. (Ill.) *N. Y. Elec. Rev.*, Dec. 8, p. 6. (Lowth.)

Telephone Switchboards. (Ill.) I. H. Farnham, Boston Elec. Club. *Md. Lt. & Ht.*, Nov. 15, p. 553.

Long Distance Telephoning. *Elec. Rev.; Sci. Am.*, Nov. 3. p. 275.

Combination Telephone. (Note.) *Lond. Elec. Engr.*, Nov. 16, p. 397.

New Telephone Exchange System. (Ill.) *West. Elecn.*, Nov. 10, p. 247. (C. E. Scribner.)

Van Size's Telephone Exchange System. (Ill.) *Elec. World*, Dec. 8, p. 300.

Practical Telephony. (Ill.) T. D. Lockwood. *West. Elecn.*, Nov. 3, p. 231; Nov. 17, p. 259; Dec. 15, p. 304.

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Anti-Induction Telephone Devices. (Corr.) J. R. Quain. *Elec. World*, Dec. 22, p. 324

Magneto Call with Manual Telephone Switch. (Ill.) *West. Elecn.*, Dec. 15, p. 307.

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The Telephone Question in Chicago. *West. Elecn.*, Dec. 8, p. 290; Dec. 22, p. 314. (Agitation to reduce rates.)

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The Cushman Telephone Case. *Elec. World*, Nov. 10, p. 252. (Injunction granted at Chicago against Cushman for infringement of Bell patents.)

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Telephone Statistics. *Elec. World*, Nov. 3, p. 243.

The Phonograph and Graphophone. (Corr.) A. A. C. Swinton. *Lond. Elec. Rev.*, Nov. 9, p. 530.

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The Phonograph-Graphophone. Bos. Soc. Arts. *Md. Lt. & Ht.*, Nov. 15, p. 558.

Edison's Perfected Phonograph. Col. Gouraud. Soc. Arts. *Eng.*, Nov. 30, p. 534.

Edison's Phonograph Works at Orange, N. J. *N. Y. Elec. Rev.*, Dec. 1, p. 1.

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Apparatus for Transmitting Sounds to a Distance by Means of Light. (Ill.) L. J. LePontois. *Sci. Am. Supp.*, Dec. 15, p. 10,803.

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ELECTRIC LIGHT, Etc.

Van Depoele Incandescent System. (Ill.) *West. Elecn.*, Dec. 29, p. 328.

The Waterhouse Arc Lamp. (Ill.) *Elec. World*, Nov. 3, p. 241; *West. Elecn.*, Nov. 3, p. 229; *N. Y. Elec. Rev.*, Nov. 3, p. 8; *Md. Lt. & Ht*, Nov. 1, p. 497; *Lond. Elec. Rev.*, Dec. 28, p. 717; *N. Y. Elec. Engr.*, Dec., p. 575.

The "Mayo" Dynamo and Lighting System. (Ill.) *Elec. World*, Dec. 29, p. 344.

The Colburn Arc and Incandescent System. (Ill.) *Elec. World*, Nov. 24, p. 277; *Lond. Elec. Engr.*, Dec. 7, p. 470.

Improved Portable Electric Light Apparatus. (Ill.) *Sci. Am.*, Nov. 17, p. 310. (S. Charlesworth & Co.—Suez Canal.)

Charlesworth's Portable Projector Apparatus. (Ill.) *N. Y. Elec. Rev.*, Nov. 24, p. 3.

Sunbeam Lamps. *Lond. Elec. Engr.*, Nov. 9, p. 385.

The Pieper Arc Lamp. (Ill.) *Eclairage à l'Électricité; Lond. Elecn.*, Nov. 23, p. 73.

A New Arc Lamp. (Note.) *Lond. Elecn.*, Nov. 23, p. 69. (Chapman & Dearing.)

The Puydt Arc Lamp. (Ill.) *Eclairage à Électricité; Lond. Elecn.*, Dec. 28, p. 226.

An Electric Arc Lamp. C. L. Baker. *Indust.*, Dec. 21, p. 600.

The Gerard Arc Lamp. (Ill.) *Elec. World*, Nov. 17, p. 264.

A New Time Switch for Lamp Circuits and Secondary Batteries. (Ill.) (W. F. Stocker.) *Elec. World*, Dec. 8, p. 298.

Storage Battery Lighting in America. *Elec. World; Lond. Elec. Rev.*, Dec. 14, p. 659. G. B. Prescott. *Elec. World*, Dec. 1, p. 286.

New Lamp-holder. (Ill.) *Lond. Elec. Engr.*, Nov. 16, p. 405. (Messrs. Appleton, Burbey & Williamson.)

Crompton's Switch-Boards at the Whitehall Installation. (Ill.) *Lond. Elec. Engr.*, Nov. 2, p. 369.

A Guard Against Incandescent Lamp Breakage. (Ill.) *West. Elecn.*, Dec. 8, p. 295. (E. H. Johnson.)

Improvements in Electric Light Fixtures. (Ill.) *N. Y. Elec. Rev.*, Dec. 29, p. 1. (Messrs. Oxley, Giddings & Enos.)

The Paiste Incandescent Switch. (Ill.) *Elec. World*, Nov. 24, p. 274.

Novel Globes for Electric Lamps. (Ill.) (S. Heimann.) *Elec. World*, Dec. 15, p. 312.

A New Mast Arm for Arc Lights. (Ill.) (Russell Elec. Mf'g. Co.) *Elec. World*, Dec. 8, p. 304.

Improved Electric Light Reflectors. (Ill.) *Elec. World*, Dec. 1, p. 291. (Wheeler Reflector Co.)

Uptown Edison Station, New York. (Ill.) *Elec. World*, Nov. 3, p. 241.

An Isolated Lighting Plant at Pittsburgh, Pa. *Elec. World*, Dec. 15, p. 318. (Edison.)

The Edison System in New York. (Ill.) *N. Y. Elec. Rev.*, Nov. 10, p. 8; *West. Elecn.*, Nov. 3, p. 229.

An Interesting Electric Light Plant. *N. Y. Elec. Rev.*, Nov. 17, p. 5; (E. L. Striker Estate, New York.)

Leavenworth Heisler Station. (Ill.) *West. Elecn.*, Dec. 22, p. 314.

A Model Brush Plant. (Ill.) *West. Elecn.*, Nov. 10, p. 242. (Cincinnati, O.)

Chicago Electric Lighthouse. (Ill.) *West. Elecn.*, Nov. 17, p. 255.

New Electric Lighting Building in Philadelphia. (Edison.) *Sci. Am.; Lond. Elec. Engr.*, Dec. 21, p. 499; *Sci. Am.*, Dec. 8, p. 358.

Lighting the Equitable Building, Boston. (Ill.) *Elec. World*, Dec. 8, p. 305; *N. Y. Elec. Rev.* Dec. 8, p. 2; *Md. Lt. & Ht.*,, Dec. 6, p. 630.

A Model Westinghouse Central Station. (Ill.) (East Liberty, Pa.) *Elec. World*, Nov. 3, p. 242.

The Thomson-Houston Station at Malden, Mass. (Ill.) *Elec. World*, Dec. 15, p. 315; *N. Y. Elec. Rev.*, Dec. 15, p. 9

Electric Lighting at Hagerstown, Md. *N. Y. Elec. Rev.*, Dec. 15, p. 6.

The Electric Lights Under the Cascade Mountains. How it is Done. *N. Y. Elec. Rev.*, Dec. 22, p. 9.

Electric Light on a Steamer. (Ill.) *N. Y. Elec. Rev.*, Nov. 3, p. 9. ("Connecticut.")

The Brush Lighting Plant for the Man of War "Boston." (Ill., *Elec. World*, Nov. 3, p. 238.

Electric Light Extensions at Olympia. *Lond. Elec. Rev.*, Dec 21. p. 685.

Paddington and the Electric Light. *Lond. Elec. Rev.*, Dec. 14, p. 636.

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The Electric Light at Cannock Chase. (Note.) *Lond. Elec. Engr.*, Dec. 21, p. 499. (Collieries.)

The West Brompton Central Station. (Ill.) *Lond. Elec. Engr.*, Dec. 14. p. 482.

Electric Lighting in Bristol. *Lond. Elec. Engr.*, Dec. 7, p. 464.

Pritchett's Holborn Lighting Station. (Ill.) *Lond. Elec. Engr*, Nov. 30, p. 442.

Installations. (Note.) *Lond. Elec. Engr.*, Nov. 16, p. 400. (Mentmore, Savoy Mansions, etc.)

The Deptford Central Lighting Station. (Ill.) *Lond. Elecn.*, Nov. 2, p. 818; *Elec. World*, Dec. 8, p. 299; *N. Y. Elec. Rev.*, Dec. 15, p. 2.

The Whitehall Central Electric Light Station. *Indust.* Nov. 2, p. 424.

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Central Station Practice in Germany. *Md. Lt. & Ht.*, Nov. 22, p. 582; *Lond. Elecn.*, Dec. 7 p. 131.

Notes on Electric Lighting in Italy. *Lond. Elec. Engr.*, Nov. 16, p. 403.

The Vienna Central Electric Light Station. *Indust.*, Nov. 23, p. 506; *Lond. Elec. Engr.*, Dec. 7, p. 461.

Electric Lighting at the Paris Exhibition. *Indust.*, Nov. 30, p. 535; *Lond. Elec. Engr.*, Dec. 7, p. 459.

Electric Lighting in Brussels. *Indust.*, Nov. 30, p. 535.

Electric Lighting in the Argentine Republic. *Lond. Elec. Rev.*, Dec. 14, p. 664.

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The Edison Glow Lamp Patents. *Indust.*, Dec. 21, p. 605.

Incandescent Lamp Patents. (Edison & Swan *vs.* Holland.) *Lond. Elec. Rev.*, Dec. 7, p. 638; *Lond. Elecn.*, Dec. 7, p. 143; Dec. 14, p. 175; Dec. 21, p. 200; Dec. 28, pp. 219. 227; *West. Elecn.*, Dec. 29, p. 332.

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The Cost of Electric Street Lighting. *Sci. Am.*, Dec. 15, p. 372.

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Collisions at Sea.—Ship's Lights. (Ill.) (Corr.) S. H. Terry. *Eng.*, Nov. 2, p. 428; Dec. 7, p. 563.

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The Financial Position of the London Electric Supply Corporation. *Lond. Elecn.*, Nov. 9, p. 20.

ELECTRIC MOTORS.

The Tesla Motor and Westinghouse Station Switch-Board Arrangement. (Ill.) *Lond. Elecn.*, Nov. 9, p. 18; *Lond. Elec. Engr.*, Nov. 9, p. 390.

The New Card Electric Motor. (Ill.) *Elec. World*, Nov. 10, p. 255; *West. Elecn.*, Nov. 3, p. 230; *N. Y. Elec. Rev.*, Nov. 10, p. 3; *Md. Lt. & Ht.*, Nov. 8, p. 523.

The Baxter Motor at the Julien Station, New York. (Ill.) *Elec World*, Nov. 3, p. 239; *Sci. Am*, Nov. 17, p. 310.

Baxter Motors of Large Horse Power. (Ill.) *Elec. World*, Nov. 24, p. 275; *N. Y. Elec. Rev.*, Nov. 24, p. 8.

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The New Sprague Motor. (Ill.) *Lond. Elec. Engr.*, Dec. 21, p. 502. (The "Boston")

The Belding Motor. (Ill.) *West. Elecn.*, Dec. 15, p. 302.

Thomas' Electric Motor. (Ill.) *West. Elecn.*, Dec. 15, p. 302.

The New Thone Electric Motor. (Ill.) *West. Elecn.*, Dec. 8, p. 290.

Electrical Elevators for the Eiffel Tower. *Elec. World*, Dec. 1, p. 291.

An Electric Crane by Messrs. Crompton & Co. (Ill.) *Lond. Elecn.*, Nov. 30, p. 102; *Lond. Elec. Rev.*, Nov. 30, p. 599; *Lond. Elec. Engr.*, Nov. 30, p. 443, *Elec. World*, Dec. 22, p. 326.

Organ Playing by Electricity. (Ill.) W. S. Chester. *Elec. World*, Nov. 10, p. 251; *West. Elecn.*, Nov. 17, p. 254.

Electric Motor and Rotary Pump. (Ill.) *Elec World*, Dec. 1, p. 289. (Goulds Manufacturing Company.)

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Electric Power in the West. *N. Y. Elec. Rev.*, Dec. 15, p. 8.

Electric Power in a Straw Hat Factory. (Ill.) *Elec. World*, Dec. 1, p. 289; *N. Y. Elec. Rev.*, Dec. 1. p. 8.

French Submarine Boat. *N. Y. Elec. Rev.*, Dec. 29. p. 3; *Science*, Dec. 21, p. 308.

Spain's New Electric Torpedo Boat. *N. Y. Elec. Rev.*, Nov. 10, p. 1; *Lond. Elec. Rev.*, Dec. 14, p. 663. ("The Peral.")

Electrical Boats. *Sci. Am.*, Nov. 10, p. 290.

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Electricity as Applied to Mining. Brit. Assn. *West. Elecn.*, Nov. 17, p. 260.

Electricity as Applied to Mining. (Ill.) Frank Brain. *Sci. Am. Supp.*, Dec. 8, p. 10,780; *Md. Lt. & Ht.*, Dec. 13, pp. 656-7.

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A Motor Preferred to a Steam Engine. (Ill.) *Elec. World*, Dec. 29, p. 340. (Thomson-Houston Motor at New Bedford, Mass.)

A Testing Room for Electric Motors. (Ill.) G. W. de Tunzelmann. *Eng., Elec. World*, Dec. 29, p. 339.

Electric Transmission of Power at Weissembach. *Md. Lt. & Ht.*, Dec. 6, p. 633.

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A Basis from which to Calculate Charges for Electric Motor Service. H. C. Lufkin, Nat. Elec. Lt. Ass'n. *Sci. Am. Supp.*, Nov. 3, p. 10,696.

The Kearney (Neb.) Water Power and Electric Distribution Plant. (Ill.) D. C. Jackson. *N. Y. Elec. Engr.*, Dec. p. 573.

ELECTRIC RAILWAYS, Etc.

The Daft Elevated Railway Motor "Ben Franklin." (Ill.) *Elec. World*, Dec. 1, p. 286; Dec. 22, p. 325; *N. Y. Elec. Rev.*, Dec. 1, p. 1; *Sci. Am.*, Dec. 8, p. 361; *Md. Lt. & Ht.*, Dec. 6, pp. 629, 638; *Science*, Dec. 14, p. 281; *Lond. Elecn.*, Dec. 14, p. 170.

The "Julien" Electric Locomotive at Birmingham. *Lond. Elec. Engr.*, Nov. 9, p. 383; *Science*, Dec. 7, p. 270; *Lond. Elecn.*, Nov. 16, p. 51; *Indust.*, Nov. 9, p. 542.

Electrical Storage Street Cars. *Sci. Am.*, Dec. 8, p. 361. (Julien Elec. Co., Madison Ave.)

A Closed-in Car for Electric Railways. (Note.) E. Verstraete. *Lond. Elec. Engr.*, Nov. 2, p. 358.

An Electric Tramcar in Paris. *Electricien, Elec. World*, Nov. 17, p. 368; *N. Y. Elec. Engr.*, Dec., p. 587.

The New Sprague Electric Street Car Truck. (Ill.) *Elec. World*, Dec. 1, p. 287; *N. Y. Elec. Rev.*, Dec. 1, p. 10.

The Hauss Electric Railway. *Science*, Dec. 21, p. 301.

The Silvey Alternating Current Street Car System. (Ill.) *West. Elecn.*, Nov. 24, p. 266; *Elec. World*, Dec. 1, p. 288.

The Ries Electric Railway. *Lond. Elec. Rev.*, Nov. 16, p. 538.

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Boston Electric Railway. *Md. Lt. & Ht.*, Dec. 6, p. 637. (Brighton-Boston.) Nov. 27, p. 709.

An Electric Mountain Railway. *N. Y. Elec. Rev.*, Nov. 10, p. 1. (Burgenstock.)

The San Jose, Cal., Electric Road. (Ill.) (Fisher System.) *Elec. World*, Nov 24, p. 275; Dec. 22, p. 327.

The Electric Road at St. Catherine's, Can. *Elec. World*, Nov. 24, p. 280.

An Accumulator Locomotive. *Lond. Elec. Engr.*; *Elec. World*, Nov. 3, p. 243. (Victor Works, Holloway.)

The Thomson-Houston Road at Lynn, Mass. (Ill.) *Elec. World*, Dec. 8, p. 303; *Md. Lt. & Ht.*, Dec. 6, p. 636; Dec. 13, p. 657; *N. Y. Elec. Rev*, Dec. 8, p. 8.

Some New Thomson-Houston Electric Roads. *Elec. World*, Nov. 24, p 279; *Md. Lt. & Ht.*, Nov. 15, p. 560. Omaha and Council Bluffs, Wichita, Lynn, Ansonia, Syracuse, Des Moines, Topeka, Alliance, North Adams, Danville, Scranton, Bangor, Boston, Seattle, Cleveland, Louisville.

New Electric Railway Works. *N. Y. Elec. Rev.*, Nov. 24, p. 8. (Thomson-Houston.)

Electric Railways. (Ill.) *Lond. Elec. Engr.*, Nov. 23, p. 422. (Thomson-Houston Method.) At the Italian exhibition. *Indust.*, Nov. 30, p. 533.

The Danville, Va., Electric Railway. (Ill.) *Elec. World*, Dec. 29, p. 340; *Md. Lt. & Ht.*, Dec. 27, p. 708.

New Sprague Road at Akron, Ohio. *Elec. World*, Nov. 17, p. 266; *West. Elecn.*, Nov. 24, p. 266.

The Sprague (West End) Electric Road, Boston. (Ill.) *Elec. World*, Dec. 29, p. 341; *West. Elecn.*, Dec. 29, p. 331; *Science*, Dec. 28, p. 324; *N. Y. Elec. Rev.*, Dec. 29, p. 2.

The St. Joseph, Mo., Electric Road. *Elec. World*, Dec. 22, p. 329. *N. Y. Elec. Rev.*, Dec. 22, p. 1. (Sprague.)

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Magnetos. F. B. Badt. *West. Elecn.*, Dec. 8, p. 295.

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The "Andrews" and "Lang" Switches. (Ill.) *Elec. World*, Dec. 15, p. 316.

The Bryant Switch. (Ill.) *Elec. World*, Nov. 10, p. 255.

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Novel Earth Plate. *Elec. World*, Nov. 10, p. 253. (Signor Baretta.)

Electric Temperature Regulators. (Ill.) *N. Y. Elec. Rev.*, Nov. 3, p. 2; *Md. Lt. & Ht.*, Dec. 13, p. 658.

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A Burglar and Fire Alarm. (Ill.) *West. Elecn.*, Dec. 1, p. 277.

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Eco Magneto Watchman's Clock. C. A. White, Boston Soc. Arts. *Md. Lt. & Ht.*, Nov. 1, p. 501.

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Heating by Electricity. Elias E. Ries. *Elec. World*, Nov. 10, p. 256.

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AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

DIRECTORY OF MEMBERS, HONORARY MEMBERS AND ASSOCIATES.

May 1st, 1889.

Abernethy, J. P., 53 City Hall, Cleveland, O.
Acheson, Edw. G., Box 952, Pittsburgh, Pa.
Adams, H. C., 115 Broadway, New York.
Ahearn, T., Ottawa, Ont.
Anderson, A., 85 North Common, West Lynn, Mass.
Andrews, Wm. S., 5 & 6 Lumber Exchange, Minneapolis, Minn
Anthony, Prof. W. A., Manchester, Conn.
Backstrom, Chas. A., 60 William St., New York.
Batcheller, B. C., 71 Broadway, New York.
Batchelor, Chas., 33 W. 25th St., New York.
Bates, D. H., 44 Broadway, New York.
Bates, J. H., care of W. H. Cole, 504 W. 53rd St., New York.
Barrett, John A., 18 Cortlandt St., New York.
Barton, E. M., Western Electric Co., Chicago, Ill.
Bayly, B., Capetown, Cape of Good Hope, Africa.
Beattie, John, Jr., Fall River, Mass.
Bell, Prof. A. Graham, Washington, D. C.
Bergholtz, Herman, Thomson-Houston Electric Co., Lynn, Mass.
Berliner, E., Columbia Road, bet. 14th and 15th Sts., Washington, D. C.
Bernard, E. G., Genesee Hotel, Utica, N. Y.
Birdsall, E. T., 107 E. 70th St., New York.
Blackwell, R. W., 27 10th Ave., New York.
Blake, Edward, 55 Oliver St., Boston, Mass.
Blake, Henry W., 16 Broad St., New York.
Blodgett, Geo. W., Room 20, B. & A. R. R. Depot, Boston, Mass.
Blood, W. H. Jr., Thomson-Houston Electric Co., Lynn, Mass.

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Bock, Leo, Jr., Dakota Flats, 72nd St., New York.
Bogart, A. Livingston, 22 Union Square, New York.
Bosch, Adam, Fire Alarm Telegraph, Newark, N. J.
Bottomley, Harry, Thomso -Houston Electric Co., Lynn, Mass.
Bowman, A. H., Allentown, Pa.
Bracken, Wm., 120 Broadway, New York.
Brackett, Prof. Cyrus F., Princeton, N. J.
Bradley, C. S., 61 Buena Vista Ave., Yonkers, N. Y.
Brady, Paul T., Cooperstown, N. Y.
Briner, C. J., 310 No. 3d St., St. Louis, Mo.
Brooks, David, East Washington Lane, Germantown, Pa.
Brooks, E. H., Lebanon, Pa.
Brophy, Wm., 51 Salem St , Worcester, Mass.
Brown, Chas A., Western Electric Co., Chicago, Ill.
Brown, Jo. Stanford, 63 Livingston St., Brooklyn, N. Y.
Browning, Howard L., 40 Tweddle Building, Albany, N. Y.
Brush, C. F., Cleveland, O.
Buckingham, Chas L., 195 Broadway, New York.
Byllesby, H. M., Westinghouse Electric Co., Pittsburgh, Pa.
Case, Willard E., 6 Fort St., Auburn, N. Y.
Chamberlain, J. C., 85th St. and Madison Ave., New York.
Cheever, Chas. A., 13 Park Row, New York.
Child, Frank W., 40 Broadway, New York.
Childs, W. H., Brattleboro, Vt.
Chinnock, C. E., 65 Fifth Ave., New York.
Chubbuck, H. Eugene, Box 421, Springfield, O.
Church, Wm. Lee, Box 1000, Pittsburgh, Pa.
Clark, Ernest P., 159 Chambers St., New York.
Clarke, Chas. L., 40 Walnut St., East Orange, N. J.
Cleveland, W. B., 183 Seneca St,, Cleveland, O.
Coffin, C. A., 620 Atlantic Ave., Boston, Mass.
Colby, E. A., 606 High St., Newark, N. J.
Collins, W. Forman, 624 Atlantic Ave., Boston, Mass
Compton, Prof. Alfred G., 17 Lexington Ave., New York
Conant, Thos. P., 44 Broadway, New York,
Condict, G. Herbert, 4720 Green St., Germantown, Pa.
Cowles, Alfred H., Lockport, N. Y.
Crane, W. F. D., 919 Spruce St., Philadelphia, Pa.
Crocker, Francis B. 322 Seventh Ave., New York.
Cross, Prof. Charles R., Mass. Inst. Technology, Boston, Mass.
Curtis, Chas. G., 114 E. 30th St., New York.
Curtiss, Geo. F., Thomson-Houston Electric Co., Lynn, Mass.

Cuntz, Johannes H., 137 Hudson St., Hoboken, N. J.
Cushman, Holbrook, 337 W. 22nd St., New York.
Cuttriss, Chas., Room 16, 1 Broad St., New York.
Daft, Leo, Plainfield, N. J.
Dana, R. K., 16 Cliff St., New York.
Danforth, A. H., South Pueblo, Cal.
Danvers, Alan, The Anglo-Portugese Telegraph Co., Lisbon, Portugal.
Danvers, Ernest. (Casilla 74) Bajada 48 Rosario de Santa Fe, Argentine Republic
Davis, D. L., Salem, O.
Davis, Chas. M., Box 774, Pueblo, Colorado.
Davis, Joseph P., 18 Cortlandt St., New York.
Davis, Minor M., Room 16, 5 Dey St., New York.
Delany, P. B., 84 Broad St., New York.
Denton, Prof. J. E., Stevens Institute, Hoboken, N. J.
Dickenson, S. S., Hazel Hill, Guysborough Co., N. S.
Dickerson, E. N., Jr., 5 Beekman St., New York.
Diehl, Philip, 508 Morris Ave., Elizabeth, N. J.
d'Infreville, Georges, 195 Broadway, New York.
Dobbie, Robert S., 327 Eighth Ave., New York.
Doremus, Dr. Chas. A., 92 Lexington Ave., New York.
Duncan, Dr. Louis, Johns Hopkins University, Baltimore, Md.
Durant, Geo. F., 322 Pine St., St. Louis, Mo.
Dyer, R. N., 40 Wall S., New York.
Edison, Thomas A., Orange, N. J.
Elliot, Frank L., 922 Broadway, Oakland, Cal.
Emmet, H. L. R, 36 Cortlandt St., New York
Farmer, Prof. Moses G., Eliot, Me.
Farnham, Isaiah H., 50 Pearl St., Boston, Mass
Field, C. J., 56 Garfield Building, Brooklyn, N. Y.
Field, Stephen D., Stockbridge, Mass.
Fielding, Frank E., Virginia City, Nev.
Flack, J. Day, Edison Lamp Co., Harrison, N. J.
Fleming, W. H., care of Electric Club, 17 E. 22nd St., New York.
Fleming, Dr. Walter M., 66 Madison Ave., New York.
Ford, Ellsworth, Ottumwa, Ia.
Foster, Horatio A., 425 E. 24th St., New York.
Fuller, Levi K., Brattleboro, Vt.
Garratt, Dr. Allan V., 18 Cortlandt St., New York.
Garrette, E. W., Sunset Telephone Co., Sacramento, Cal.
Garver, M. M 645 High St., Newark, N. J.
Geyer, Prof. Wm E., Stevens Institute, Hoboken, N. J.
Giles, W. A., 120 Broadway, New York.

Gilliland, E. T., 179 West End Ave., New York.
Gisborne, Hartley, Qu. Appelle Station, Assa. Dist. N. W. Territory, Can.
Goldmark, Chas. J., 963 Park Ave., New York.
Gould, Chas. W., 2 Wall St., New York.
Green, Dr. Norvin, 195 Broadway, New York.
Griscom, W. W., Philadelphia, Pa.
Gutmann, Ludwig, Box 574, Ft. Wayne, Ind.
Hall, Clayton C., 810 Park Ave., Baltimore, Md.
Hall, G. C. T., 84 Globe Building, St. Paul, Minn.
Hall, Henry D., Mount Vernon, N. Y.
Hamblet, James, (Box 3393), 195 Broadway, New York.
Hamilton, Geo. A., corner Greenwich and Thames Sts., New York.
Hammer, W. J., 23 Rowland St., Newark, N. J.
Hansell, Wm., Nevada, Iowa.
Harding, Frank R., 36 F St., Washington, N. W., D. C.
Harding, H. McL., 16 Broad St., New York.
Haskins, Col. C. H., 123 Fifth Ave., New York.
Harvey, Wirt B., Room 21, 43½ Madison St., Memphis, Tenn.
Hazard, Col. R. R., 120 Broadway, New York.
Haynes, F. T. J., Belmont Villa, Taunton, Eng.
Healy, Clarence L., 18 Broadway, New York.
Hebard, George W., 120 Broadway, New York.
Henderson, A. H., 433 First St., Baltimore, Md.
Henshaw, F. V., 79 State Street, Brooklyn, N. Y.
Hering Carl, 3816 Spring Garden St., Philadelphia, Pa.
Herzog Dr. F. Benedict, 36 Broad St., New York.
Higgins, Edward E., 202 Main St., Buffalo, N. Y.
Hochhausen, Wm., 196 to 216 Willoughby St., Brooklyn, N. Y.
Hopkins, J. H., 2715 Lucas Ave., St. Louis, Mo.
Hotchkiss, Clark B., 60 E. 66th St., New York.
Houston, Prof. E. J., 1521 Mt. Vernon St., Philadelphia, Pa.
Howell, John W., Edison Lamp Co., Harrison, N. J.
Howson, Hubert, 38 Park Row, New York.
Hubrecht, Dr. H. F. R., Directory Nederlandsche Bell Teleph., Amsterdam, Holland.
Humphreys, C. J. R., Lawrence, Mass.
Hunter, Rudolph M., 926 Walnut St., Philadelphia, Pa.
Hyde, J. W., 36 Taylor St., Springfield, Mass.
Idell, F. E., 41 Dey St., New York.
Ihlder, John D., Yonkers, N. Y.
Insull, Samuel, Schenectady, N. Y.
Iselin, Henry S., 775 Greenwich St., New York.

Ives, Lieut. Edward B., Davids Island, N. Y.
Izard, E. M., 425 The Rookery, Chicago, Ill.
Jackson, C. H., Alleghany, Pa.
Jackson, Dugald C., Kearney, Neb.
Jackson, Francis E., Edison Lamp Co., Harrison, N. J.
Jaeger, H. J., 77 Clermont Ave., Brooklyn, N. Y.
Jenks, W. J , Room 68, 16 Broad St., New York.
Johnson, E. H., 16 Broad St., New York.
Johnston, W. J., Box 3332, New York.
Jones, F. W., Room 16, 5 Dey St., New York.
Jones, Sebastian C., Aurora, N. Y.
Judson, Wm. Pierson, 60 E. Mohawk St., Oswego, N. Y.
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